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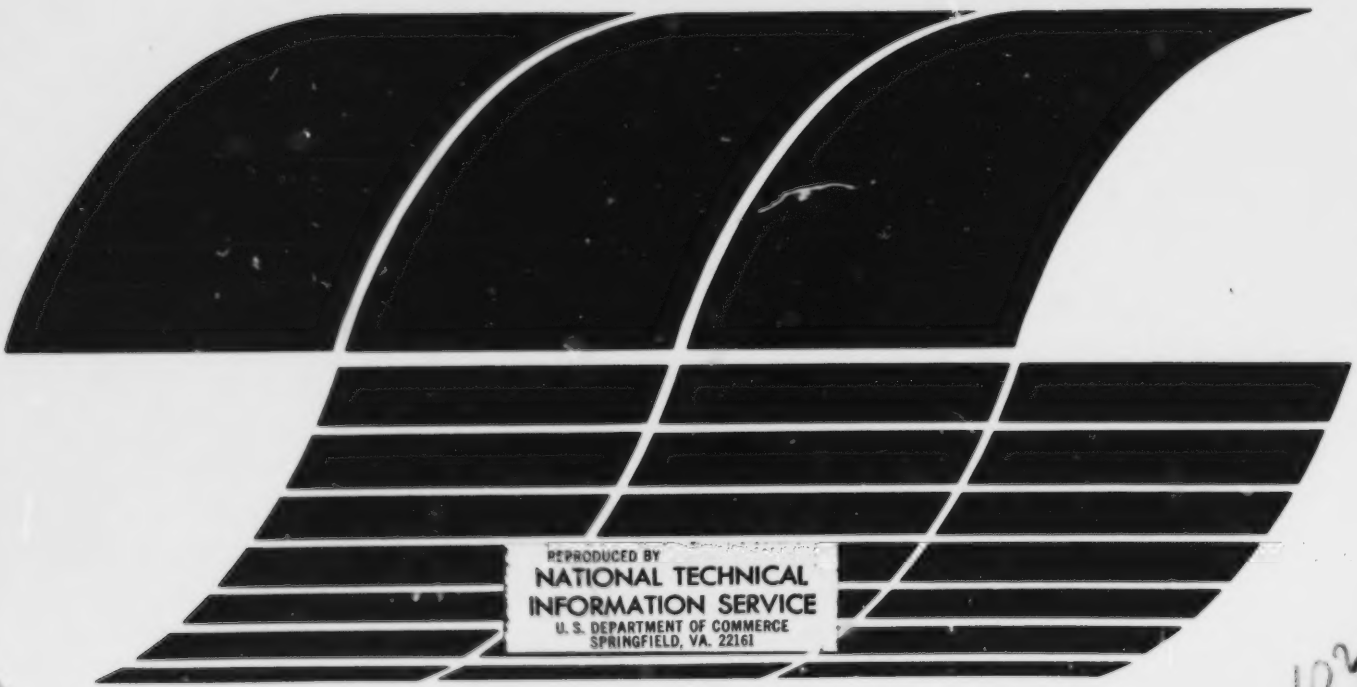

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A systems evaluation was undertaken to demonstrate the ability of miners wearing life support systems to operate conventional mining equipment and to mine coal at a test section in an active ventilated mine. Their ability to operate mining equipment and to perform other in-mine tasks was successfully demonstrated. No major difficulties were encountered in performing these tasks and the miners reported they had never been that comfortable before when working in a mine.

The life support system provided cool, clean air for the miner and did not hamper his ability to work. The system was adequate to demonstrate the miner's ability to mine coal while wearing a life support system. However, mechanical failures in the chiller and rebreather module were experienced. Additional work to develop a totally reliable life support system and further testing under ventilated conditions are required before testing in an oxygen free atmosphere.

Due to the size of the Appendices, they have been published in a separate volume, available from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, Virginia, 22161. A list of the Appendices has been included in the contents of this volume.

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TESTING PROGRAM FOR MINING COAL IN AN OXYGEN FREE ATMOSPHERE
Volume 1

by

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This report has been reviewed by the Industrial Environmental Research Laboratory-Cincinnati, U. S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, not does mention of trade names or commercial products constitute endorsement or recommendation for use.

FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report is a systems evaluation of the concept of applying an oxygen-free atmosphere to active deep coal mines. The purpose of the program was to demonstrate that miners wearing life support systems can satisfactorily operate conventional mining equipment and mine coal.

The successful application of this concept could eliminate dust inhalation and fire and explosion hazards, reduce mine drainage, and eliminate the need for rock dusting and the use of special explosion-proof equipment. Where mines produce large quantities of methane gas, capture and sale of the gas would be possible.

This report will provide key information to those interested in the feasibility of mining in an oxygen-free atmosphere or converting an existing mine to oxygen-free operation. For further information contact the Resource Extraction and Handling Division.

David G. Stephan
Director
Industrial Environmental Research Laboratory
Cincinnati

ABSTRACT

A systems evaluation was undertaken to demonstrate the ability of miners wearing life support systems to operate conventional mining equipment and to mine coal at a test section in an active ventilated mine. Their ability to operate mining equipment and to perform other in-mine tasks was successfully demonstrated. No major difficulties were encountered in performing these tasks and the miners reported they had never been that comfortable before when working in a mine.

Four life support systems, one conventional section of mining equipment, an office building and a dedicated test face in an active ventilated mine were used in the project. Minimum modification to the mining equipment was required to receive and operate the life support system.

The life support system provided cool, clean air for the miner and did not hamper his ability to work. The system was adequate to demonstrate the miner's ability to mine coal while wearing a life support system. However, mechanical failures in the chiller and rebreather module were experienced. Additional work to develop a totally reliable life support system and further testing under ventilated conditions are required before testing in an oxygen free atmosphere.

Due to the size of the Appendices, they have been published in a separate volume, available from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, Virginia, 22161. A list of the Appendices has been included in the contents of this volume.

This report was submitted in fulfillment of Project No. 14010 DZM - Phase II between the Environmental Protection Agency and Island Creek Coal Company. Also participating in this project was the Cyrus William Rice Division of the NUS Corporation.

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SECTION I

INTRODUCTION

The concept of applying an oxygen-free atmosphere to active deep coal mines involved miners using life support systems to enable them to operate mining equipment in a mine blanketed with an oxygen-free atmosphere. Preliminary conceptual studies indicated the possible success of the application in not only abating acid mine drainage but in eliminating both dust inhalation and fire and explosion hazards from mines. Other possible benefits that could occur included the elimination of rock dusting and the use of special explosion-proof equipment. In the case of mines producing large quantities of methane gas, capture and sale of this gas would be possible.

An in-depth feasibility study into this concept was conducted through a Research and Development Grant No. 14010 DZM from the Federal Water Quality Administration to Island Creek Coal Company titled "A Demonstration of a New Mining Technique to Prevent the Formation of Mine Acid in an Active Deep Mine - Phase I." The report of the study titled "Feasibility Study of Mining Coal in an Oxygen-Free Atmosphere," August, 1970, verifies the original concept. Off-the-shelf technology and equipment is available and no major technical pitfalls were foreseen.

The guidelines adopted for the feasibility study were as follows:

1. Maximum use was to be made of available equipment with no or minor modifications.

2. A demonstration mine was to be designed to use nitrogen, nitrogen plus methane, or all methane atmosphere in the mine limiting the oxygen content to a maximum of 0.1% v/v.

3. The demonstration mine was to be located adjacent to an existing active mine but not physically connected to it so that the coal handling and preparation facilities of the active mine could handle the coal produced in the demonstration mine.

4. A refuge station ventilated from the outside with normal atmosphere was to be located in the demonstration mine near the working face.

5. Conventional rubber tired, battery operated mine tractors were to be used.

6. The demonstration mine should be a one-section mine using conventional mining equipment working one shift per day.

The Phase I feasibility study report recommended the purchase and testing of prototype equipment in an active ventilated mine and the design of a demonstration mine for testing the oxygen-free concept. This program was initiated to carry out the recommendations of the Phase I feasibility study using the guidelines established for the Phase I study.

SECTION II

SUMMARY

The purpose of the program was to demonstrate that miners wearing life support systems can satisfactorily operate conventional mining equipment and mine coal. This was successfully demonstrated. Two miners equipped with life support systems operated all pieces of conventional mining equipment at a test face in an active ventilated mine and performed other in-mine tasks such as cleaning ribs, setting timber, and repairing equipment.

The specifications developed in the Phase I program were used to select the suppliers of the communication system, the rebreather, the chiller, the life support suit, as well as the mining equipment which included a cutting machine, a coal drill, a roof drill, a shuttle car, and a loading machine. The selected suppliers of the basic life support and communications systems are listed in Appendix O.

The chiller module of the life support system operated on 110V-AC power and contained a transformer which provided 24V-AC power for the rebreather. A 440V-110V transformer was mounted on the mining equipment and a 110V outlet was provided to operate the chiller module. Support racks for the rebreather and the chiller modules were fastened to the mining equipment. A mine height of 48 inches was used and every attempt was made to keep the overall equipment height below 36 inches.

The life support systems were tested in the Office and Equipment Test Building built for the project and two miners were trained in their use. Here rebreathers and chillers were also fitted to the mining equipment prior to taking the equipment into the mine.

The test face provided in the active adjacent mine required the building of stoppings, air curtains, a track crossover, a side-belt loading station, the setting of timbers, the removal of gob, and rock dusting in order to insure a safe test face that conformed to existing mining regulations. The major portion of this work was performed by the two miners assigned to the project.

The radio transmitter was installed at the mine mouth and the antenna cable hung in the mine to provide radio communications between the test face and the maintenance shop of the mine. This communications system proved highly effective and requires serious consideration for future use in coal mines.

After developing the test face, the individual miners, wearing a life support system and carrying their helmets, were taken to the test section

where the helmet was donned and they proceeded to operate the mining equipment. Each operation was documented on movie film and still photographs. Some problems did develop which caused the premature shutdown of several tests. In every case, the miner had no difficulty operating the respective pieces of machinery involved. In no way did the life support system prevent him from performing his duties.

The project, originally scheduled for eighteen months, took thirty months to complete. The 1969 Health and Safety Act changed the specifications on the mining equipment causing an increase in delivery time from fourteen to forty weeks on some pieces of equipment. The miners' strike caused a six-week delay. Delays in receiving approval to take nonpermissible equipment into the mine and in choosing miners for the project were also experienced.

Due to these many delays, the actual in-mine test period was limited to six weeks.

SECTION III

CONCLUSIONS

The adapting of a prototype life support system to conventional mining equipment and testing it in a ventilated coal mine has developed the following conclusions:

1. The life support system was adequate to demonstrate the concept of miners using life support systems while mining coal. However, the overall reliability of the system needs to be improved.

2. The communications system employing FM transceivers, provided reliable communications throughout the test period and did much to expedite the project by providing direct communication from the test face to the mine mouth. However, the noise from the mining equipment, when it was in operation, made it extremely difficult to communicate with others. A paging system, to alert the miner of incoming messages, would be helpful.

3. The hearing aid proved to be a reliable method of sensing in-mine noises. However, it created nondirectional hearing which presented problems in locating the source of the noise.

4. The helmet did not interfere with the miner's vision, nor did it present problems when he was required to bend over. The visor remained relatively clear of dust even when there was a heavy concentration. There were some complaints regarding the weight and it is suggested that a lighter unit would be more desirable.

5. The emergency rebreathing unit proved to be reliable when operated by personnel who were properly trained in its use.

6. The life support suit performed in a generally satisfactory manner. However, the mechanical chiller was highly susceptible to vibration damage. Also, the overall size and weight of the rebreather and chiller presented problems in carrying and mounting it on the mining equipment.

7. Modifications of the mining equipment to accommodate the life support system were minimal. However, the available locations on the equipment for mounting the life support system, in some cases, resulted in limiting the vision of the equipment operator and exposed the life support system to possible damage due to contact with the roof and ribs of the mine.

8. The life support system did not appreciably hinder the miner and this indicates that average present day miners, who are skilled in operating modern conventional equipment, continuous miners, or longwall mining equipment, have the skills necessary to understand and operate the life support systems.

   During the test periods miners were able to operate the units of mining equipment and perform routine maintenance tasks as well as setting roof support timbers and shoveling along rib lines.

9. The blanketing gas system and the controls for a demonstration are estimated to cost $1,154,00.. An additional capital investment of $734,760 is required for mining equipment, life support systems, and support facilities. An annual operating cost is estimated to be $778,800. Credits received for the coal mined under this program would be applied in reducing the costs. (Costs are based on 1973 levels.)

SECTION IV

RECOMMENDATIONS

The life support system tested in this program adequately demonstrated the concept of miners using life-support systems while physically mining coal. The system, however, should be refined in order to improve its acceptability and reliability and to further demonstrate its capabilities. The following recommendations are therefore extended:

1. The helmet of the life support suit, while not presenting any major problems, proved to be bulky and cumbersome. It is recommended that this unit be redesigned to make it lighter, less bulky and more comfortable.

2. The emergency rebreathing apparatus proved adequate as a life support system. However, there was a slight delay in activating the unit which could present problems under actual emergency conditions. It is recommended that further evaluations be made to determine if the unit is too difficult to activate under the emergency conditions which must be anticipated in an oxygen-free mine. It is further recommended that alternate types of emergency rebreathing apparatus be tested and evaluated.

3. The chillers were large and difficult to locate on the mining equipment. Several mechanical failures were experienced in the use of these devices. It is recommended that a review be made of their design and that improvements be made to eliminate the source of the mechanical failures. In this experimental phase, the cooling equipment that was used presented a minimum of interference in adapting it to the existing mining machines. However, alternate cooling systems, which may involve some redesign of the chiller units, appear to be desirable.

4. The communications system performed adequately, but it was difficult to use while the machinery was running, because of the noise level. It is recommended that a paging system, to alert the miner of incoming messages, be incorporated into the system. The standard hearing aid might also be incorporated into the radio circuitry to provide both hearing aid and radio reception in both ears. It is further recommended that a second microphone and hearing aid be provided to simulate stereoscopic hearing.

5. The bulk and weight of the life support system, to some appreciable degree, detracts from its acceptability. It is recommended that alternate approaches to the life support system be investigated in an

attempt to reduce the weight and bulk which must be carried by miners in the portable mode. These investigations may also provide greater flexibility of the system. A smaller and more compact life support system, to be used in the portable mode, might be plugged into the main system located on the machinery; this would help achieve the above objectives in permitting greater mobility when used in the portable mode.

6. During the redesign and adaptation of the life support system to mining equipment, the potential use of the system for mine rescue work should be recognized. It is recommended that this application be given major consideration in deciding the ultimate uses of a successful life support system of this type.

7. It is recommended that a test mine, dedicated exclusively to the use of this project, be constructed along with the associated office buildings and other outside facilities required for this type operation. Such an installation would provide for the testing of all phases of work related to testing the life support system. Upon the completion of the installation of a test mine, the complete life support system should be reviewed, redesigned and modified for testing to further enhance its capabilities and reliability, which initially appeared questionable.

Testing of the life support system should be conducted in the test mine for a minimum of twelve months under ventilated conditions. This should provide adequate time for the necessary modifications and the development of a completely reliable system.

Once a life support system considered completely reliable is developed, the inert gas systems should be installed in the test mine. The life support system would then be tested in an oxygen free atmosphere, with miners actually producing coal. This phase of the program should be conducted for a minimum of twelve months to fully insure that the system is safe and operable and economically justifiable.

SECTION V

PROJECT ORGANIZATION

This project is Phase II - Component Evaluations of a four part program being conducted under a Research and Development Grant No. 14010 DZM from the Environmental Protection Agency to Island Creek Coal Company to demonstrate that mining coal in an oxygen-free atmosphere will prevent the formation and subsequent discharge of acid mine water into streams and other water courses. The Phase I Report indicates that life support systems similar to those used by NASA in the space program can be adapted to conventional mining techniques. Technology is available to develop with a minimum of research a suitable life support system for use by coal miners and communications can be maintained between the miners.

The objectives of the program are to purchase, test, modify, and retest prototype equipment and to train a selected group of miners in the use of this equipment. This testing is to be conducted in a special test section in an active ventilated mine set aside for the exclusive use of the test crew. Mining equipment is to be operated under the direction of the test engineers by two miners equipped with life support systems. The final results of this program were to be a tested, proven, and reliable life support system for use in an oxygen-free demonstration mine, as well as the detailed design and the estimated cost for the construction and operation of a demonstration mine.

In order to accomplish these objectives, the project was broken down into several well-defined steps which were as follows:

1. The specifications in the Phase I Report for the life support and communications systems were sent out to various suppliers for quotations as to price and delivery. Island Creek's standard specifications for mining equipment were sent out for quotations for a cutter, a loader, a shuttle car, a roof bolter, and a coal drill. These quotations were received, evaluated, and purchase orders were issued.

   A plot plan (Figure 1) for the adjacent Pond Fork mine showing the location of the test facility was developed. Preliminary designs for the Office and Test Building were reviewed and detailed design drawings were made. Figure 2 is the floor plan of the Office and Test Building. See Appendix H for a listing of the design drawings. A prefabricated metal shell building (Figure 3) was chosen as the most economical type of structure to use.

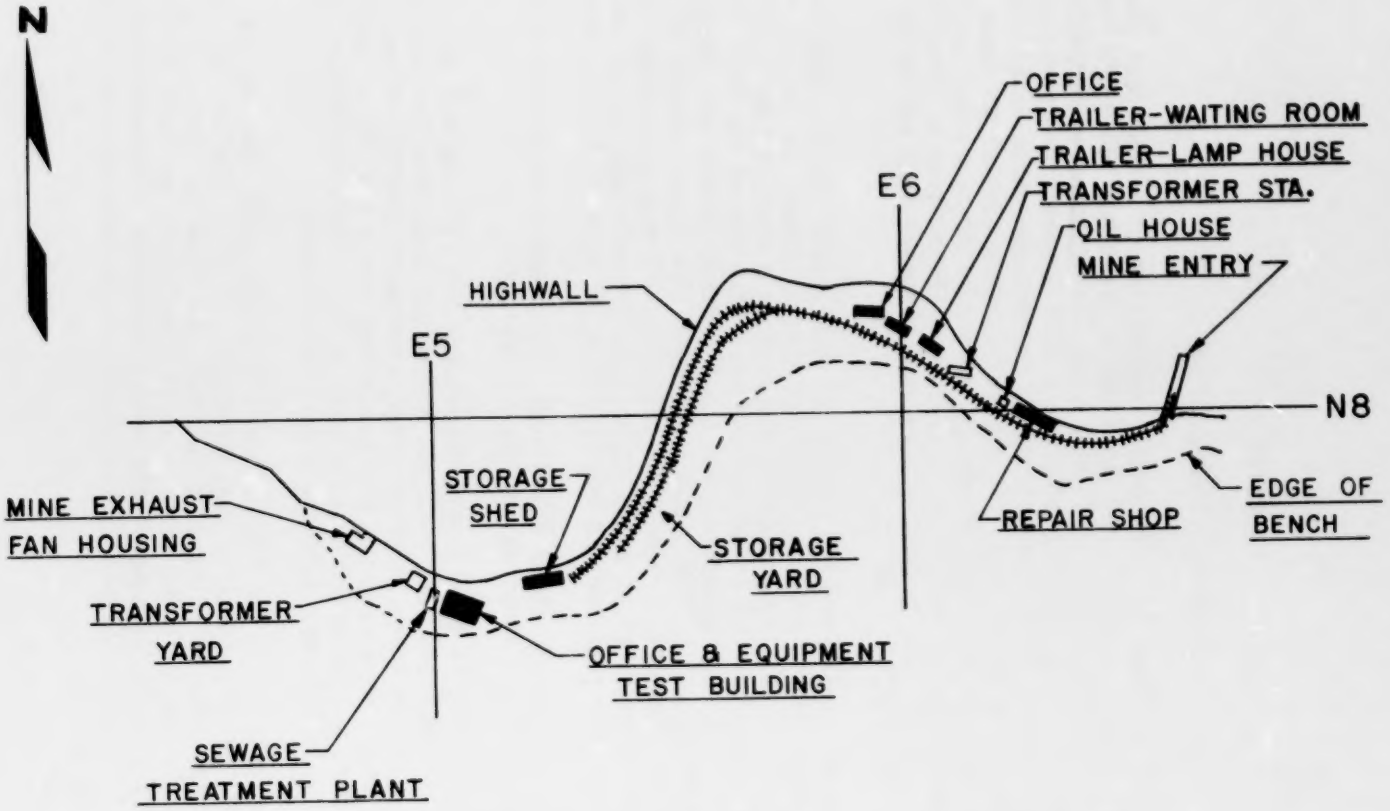


FIGURE 1
PLOT PLAN OF POND FORK MINE FACILITIES

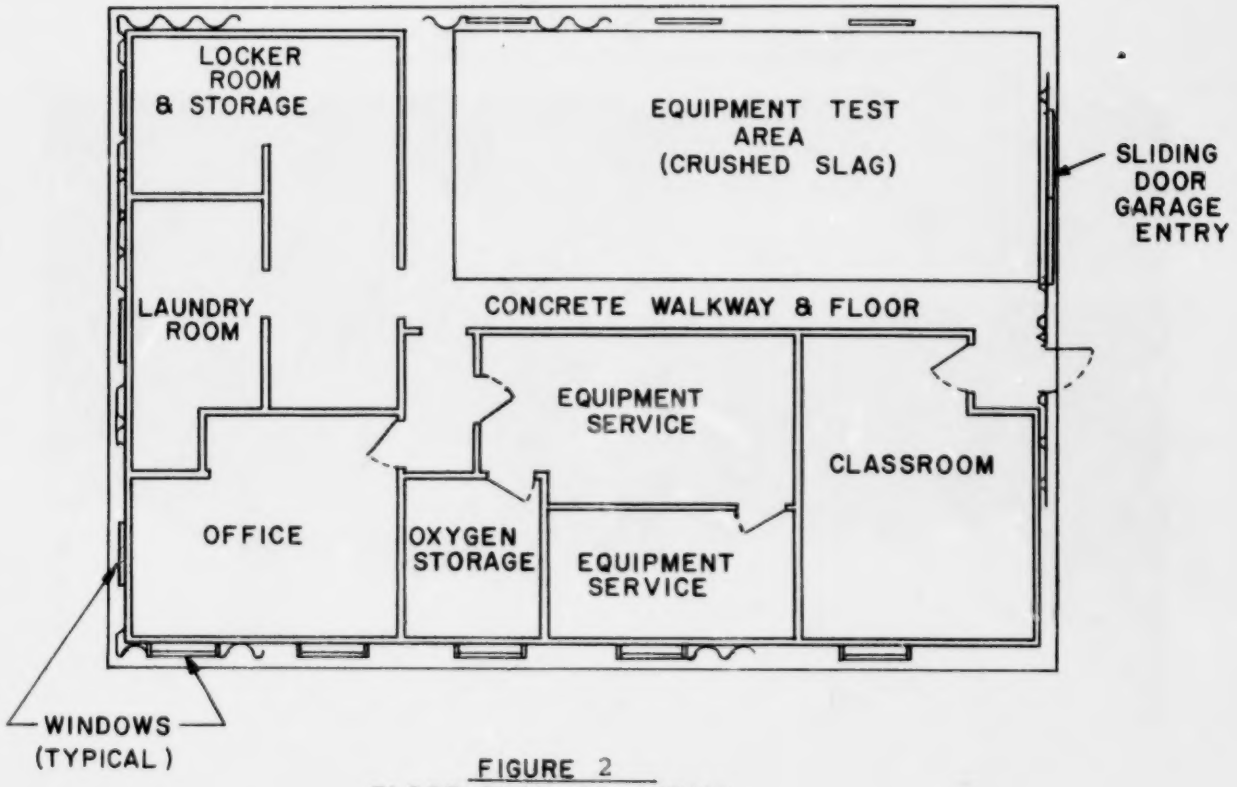


FIGURE 2
FLOOR PLAN OF OFFICE
AND EQUIPMENT TEST BUILDING

Project Office and Equipment Testing Building

Figure 3

2. Bids were received for the construction of the office building. They were unexpectedly high and the drawings were revised to reduce the cost. See Appendix I for a listing of the construction drawings. The building was constructed using the revised drawings. As the mining equipment was received, it was stored for future use. Preliminary review and testing of the miners' life support system was conducted at the laboratories of the suppliers.

3. Modifications to the mining equipment were undertaken to adapt the chiller and rebreather modules of the miners' life support systems to the equipment. Preliminary testing and evaluation of the life support system was conducted in the Office and Test Building and two miners were trained in its use.

4. A test face was established in the adjacent active ventilated mine using the two miners assigned to the project to do the major portion of the work. This involved removing the gob from the area, bolting the roof, and rock dusting the area, as well as constructing a track crossing and a belt loading station. All this work had to be completed prior to testing in the mine.

5. In-mine test programs were conducted, taking each miner individually into the mine while wearing the life support suit and carrying the helmet. At the test face, the helmet was donned, the life support system was put into operation, and the miner operated the various pieces of the mining equipment. Additional testing was conducted with both miners in the suit at the same time.

6. The necessary information was developed for the design of an oxygen-free demonstration mine. Suitable drawings were prepared and an estimate of costs to construct a demonstration mine was developed.

SECTION VI

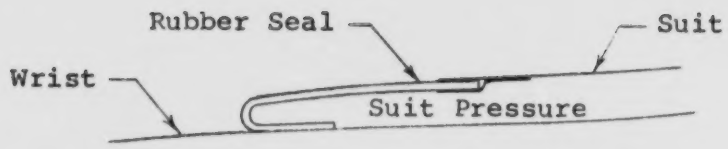
ACCEPTANCE TESTING
MINERS' LIFE SUPPORT SYSTEM

As a result of the bid analysis for the various pieces of life support equipment, Arrowhead Products Division, Federal-Mogul Corporation, Los Alamitos, California, received the contract for four life support suits, including the helmets. MSA Research Corporation of Evans City, Pennsylvania, received the contract to design and construct five rebreather and chiller modules, including the tether system. Motorola Communications and Electronics, Incorporated, Parma, Ohio, received the contract to supply the radio communications system and the Radioear Corporation of Canonsburg, Pennsylvania, were the consultants on the hearing aid. All units were to be built according to the specifications established in the Phase I Report. A meeting was held with all the suppliers present to establish responsibilities and interfaces between them.

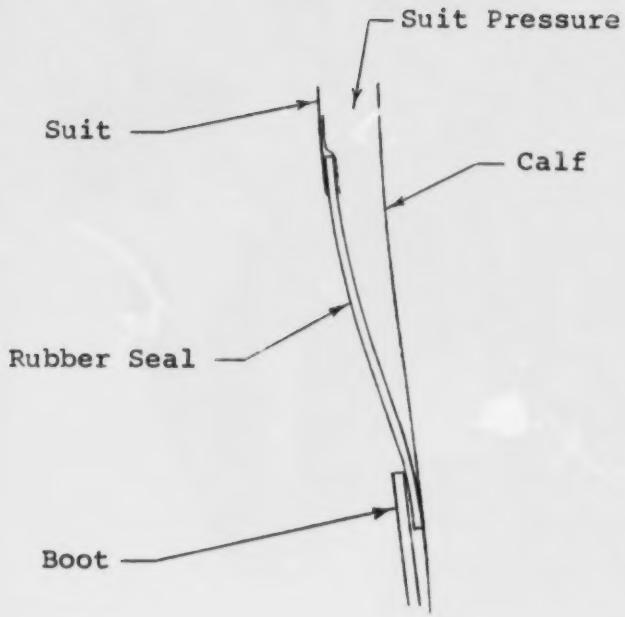
Arrowhead Products Division, Federal-Mogul Corporation, was to supply, initially, two life support suits; the remaining two to follow once appropriate sizes had been determined for the union personnel assigned to the job. One suit was sized to fit Mr. R. L. Turner, Project Mining Engineer, and the other was sized to fit Mr. R. C. Taliaferro, Project Director. The suit to fit Mr. Turner was shipped to the MSA Research Laboratories so that they could mate the rebreather system to the suit and test the complete system.

In reviewing the suit specifications with Arrowhead, it was determined that the rigid cuff and ankle seals called for in the Phase I specifications could present problems and create objections by the miners. As a result, the decision was made to use a seal similar to storm cuffs on winter clothing (see Figure 4). All suits were to have this type of seal.

MSA Research Corporation of Evans City proceeded with the design and construction of a prototype rebreather and chiller. During the design of the rebreather, MSA determined that to meet the Phase I specifications for the rebreather to provide oxygen for eight hours normally and contain an additional four hour emergency supply, the unit would weigh over seventy pounds. After reviewing this with Island Creek and RICE, the specifications were changed so that the delivered system would provide oxygen for four hours and the battery requirements were reduced from a two to a one hour duration. These changes effectively reduced the rebreather weight to approximately fifty pounds. Figure 5 shows the component parts and subassemblies used in the rebreather and Figure 6 shows the unit as assembled by MSA. This unit was mated to Arrowhead's suit and preliminary tests were conducted in MSA laboratories.

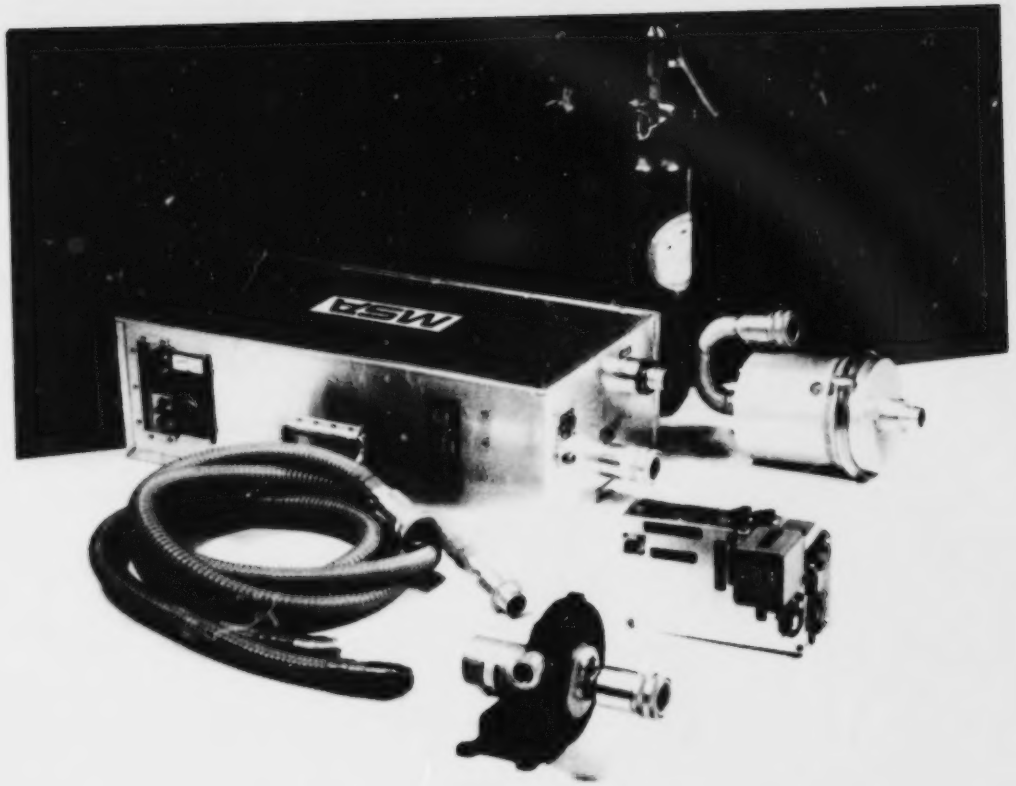


Wrist Seal



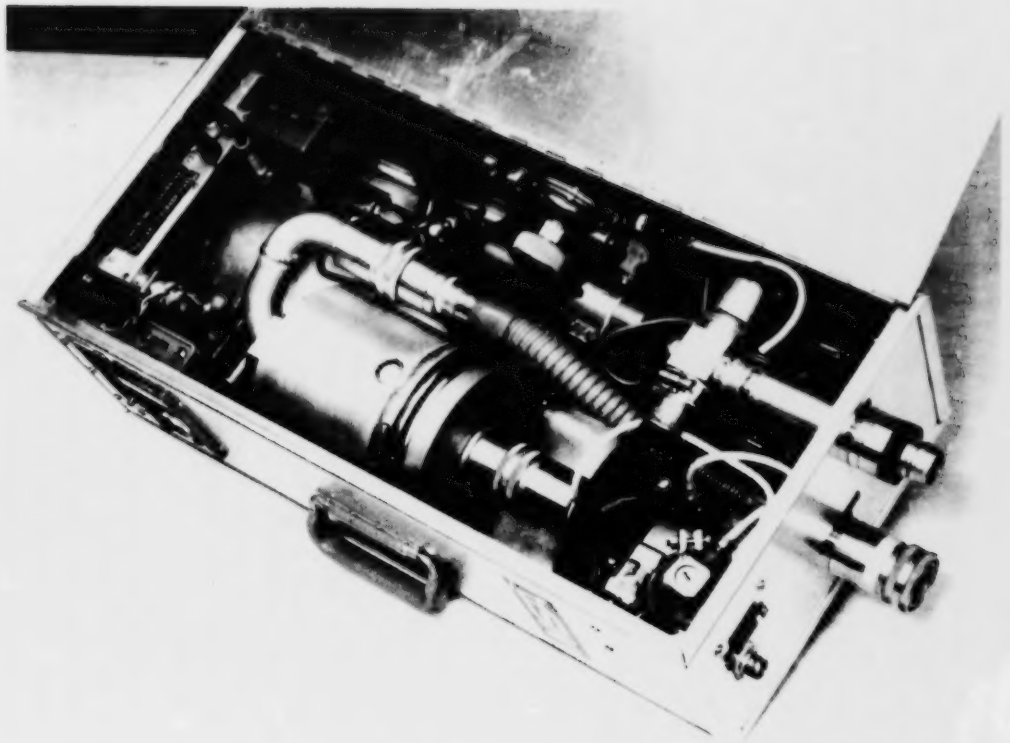
Calf Seal

FIGURE 4



Component Parts of the Mine Personnel Rebreather

Figure 5



Mine Personnel Rebreather (MPRB)

Figure 6

Mr. R. L. Turner of Island Creek Coal Company (Island) and Mr. D. J. Motz of Cyrus Wm. Rice Division-NUS Corporation (RICE) visited the MSA laboratories to inspect the system and to assist in conducting preliminary tests. The initial tests were disappointing as there were many leaks in the chiller module. The chiller module was a square unit constructed of soft copper sheeting with a bolted flanged top. The copper being soft made it impossible to maintain an air-tight seal between the flange and the cover sheet. This required a complete redesign of the chiller unit resulting in a cylindrical unit that proved satisfactory.

Upon the completion of the redesign and construction of the chiller unit, Messrs. Motz and Turner again visited MSA to test the system. Once again, the results were disappointing. The system was still not air-tight. In checking the system for leaks, it was determined that the adhesive used to assemble the tethers was failing. Flexing the tethers caused the adhesive to break away from couplings and leaks would develop. As a result, testing was postponed while MSA approached the manufacturer to determine the suitable adhesive for assembling the tethers.

One bit of important information gained through these leaks was that a leak on the suction side of the blower caused an intake of air into the system and the suit to balloon excessively. Leaks on the discharge side of the blower caused the system to evacuate and the suit to cling to the man. If the suit balloons excessively, look for the leak in the return tether from the suit to the rebreather, as this is the only part of the system under negative pressure. If the suit evacuates, the leak could be anywhere in the system except the return tether to the blower.

After the tethers had been completely reassembled, using the new adhesive, Messrs. Turner and Motz visited the MSA laboratories to test the system. When Mr. Turner donned the suit and the system was started up, odors in the suit made it impossible to continue. These odors were traced to the new adhesive. It was determined that in the future, repairs to the tethers should be cured for approximately 48 hours and be purged with air before being used. Otherwise, the adhesive odor would make it impossible to stay in the suit. In the laboratory, the tethers were placed in a low temperature oven and air-purged to hasten the evaporation of the adhesive. Testing continued the following day.

Mr. Turner donned the suit and it appeared that all leaks in the system had been resolved and the system was air-tight. At this point, two problems developed. One was that the suit ballooned or appeared to be overinflated and that every time there was movement within the suit, the trapped air would cause the helmet to rise on the head. Bending over caused the helmet to rise above the eye level. A slight movement of the foot would cause the helmet to bounce up and down on the head. This was quite annoying and a problem that had to be solved.

The second problem was controlling the oxygen flow and pressure in the system, as this appeared to be the cause of the over-inflation of the suit. Early in the program, the decision was made to use compressed oxygen to maintain a positive pressure in the system of one-half inch water column as

well as to supply the oxygen for breathing, with the suit acting as a breathing bag. It was felt that if the pressure criteria were maintained, there would be adequate oxygen in the system for breathing.

The initial pressure-sensing line was installed to control the oxygen input at the suction side of the fan. Under this arrangement, the regulator was attempting to maintain a positive one-half inch pressure while sensing a negative suction pressure of six inches. This was an impossible situation which caused the oxygen regulator to continuously dump oxygen into the system. Other points for controlling the oxygen input were investigated. The discharge side of the fan presented problems similar to the suction side, only in this case the discharge pressure of the blower would prevent the regulator from operating. The only logical place to control the oxygen flow and sense the suit pressure was a sensing line directly to the suit. An experimental system was tested in the laboratory and seemed to perform satisfactorily.

A permanent pressure-sensing line was installed inside the return tether from the suit. The sample line terminated at the tether fitting located at the suit, and exited the tether prior to the tether Quick Disconnect at the breather. A separate Quick Disconnect was provided to connect the sample lines to the rebreather. This scheme permits the sensing and control of actual in-suit pressure. Once this sample line was installed, it was found that the regulator was unable to maintain the control pressure and it was necessary to change to a lighter spring in the regulator.

Once this was done, the regulator was able to maintain an in-suit pressure of 0.4-0.6 inches water column. A separate line inside the rebreather injected the oxygen into the tether at the discharge of the blower. The sensing line in the return tether was purely a control line and did not deliver oxygen directly to the suit.

These modifications corrected the oxygen control problem by maintaining the control pressure in the suit. The problem of the trapped air within the suit, causing the helmet to rise on the head whenever there was movement within the suit had to be brought under control before the system would be acceptable.

During one of the discussions, it was suggested that an elastic stretch garmet worn over the gas-tight garment may provide the elasticity required to permit the gas within the suit to move freely about without causing the helmet to rise. To initially evaluate this concept, the long underwear was slipped over the gas-tight suit to confine the suit. The helmet rise was not as serious as it had been without the underwear. It was decided to determine what garments were available to provide this elasticity without requiring any major tailoring costs.

The investigation into several possible suits to serve as a stretch garment included such things as wrestling tights, football uniforms, women's knit tee shirts and stretch slacks as well as the standard body stocking or leotard, as it is more commonly called. The stretch jersey, slacks, and a leotard were purchased and tested. Both systems controlled the helmet rise

problem. However, the one-piece leotard proved superior. The jersey and the slacks combination gapped at the waist and created problems. As a result, it was decided to modify the leotard by installing a zipper in the front to make it easier to put on over the gas-tight suit.

Once the leotard had been modified, the complete, assembled life support system was tested. The underwear, the gas-tight suit, the stretch garment, and a standard miner's coverall made up the complete suit assembly. The system was pressurized in excess of seven inches water column. Even under this pressure, there was freedom of movement and no problem with keeping the helmet on the head. The leotard as the stretch garment proved successful in controlling this helmet-rise problem.

One of the remaining problems was to install some means of inflating the system with ambient air prior to opening the oxygen valve and to provide a gauge to indicate when the suit was at the control pressure. During the initial testing, it was observed that when inflating the suit to the control pressure using oxygen, the initial oxygen concentration would exceed 40%. This was unacceptable as the system should initially start out as close to ambient air as possible. The suit had to be filled with ambient air to meet this criteria.

In order to accomplish this, a pressure gauge was installed on the oxygen control line to directly read the in-suit pressure. In addition, a toggle valve was installed on the suction side of the blower. When this toggle valve was opened, the blower would suck room air into the system. When the gauge indicated the control pressure had been reached, the toggle valve would be closed and oxygen valve opened. When the system was put into operation in this manner, the oxygen concentration rose to approximately 25%.

This appeared to solve the control and start-up problems with the life support system. MSA completed the assembly of the remaining units and shipped them to the mine for further study.

SECTION VII

PERSONNEL SELECTION

The original plan proposed for the project in regard to the selection of people to operate the mining equipment was to select the miners from the work force at the adjacent Pond Fork mine. Selection of personnel from the work force at the adjacent mine would minimize any possible difficulties with the local union. Also, the men chosen were already available at the mine, were already members of the local union, and were familiar with the conditions existing at the mine.

Selection of the miners for the project was critical since only two miners were going to be used and they had to be able to operate each piece of mining equipment. This required experienced miners, with particular skills not always available from every mine worker. They had to be in reasonable physical condition and be able to wear the life support gear without fear. Their work records would be reviewed and each one would have to be judged a dependable and reliable member of the work force.

Before the men were chosen, however, certain criteria were established for the men and the job. Island Creek's labor relations personnel agreed that the miners should be taken from the local force at the mine, they should remain on the project for the length of the project, and upon the completion of the project should be allowed to return to their regular jobs with no loss of their benefits, which includes such things as seniority, job bidding, vacation and Christmas pay, and all compensation benefits. They would receive the top rate of pay for the underground miner as specified by their current contract for the length of the project. Upon returning to the work force, they would revert to the same pay level they had before transferring to the project. Since only two miners were being used, their selection should be based on qualification only and not seniority.

With these criteria, Island approached the District 17 office to the United Mine Workers of America in Charleston, West Virginia, to obtain their approval of the criteria and to obtain their permission to approach the local union to seek their permission to post the jobs and ask for volunteers for the projects. The District 17 office offered their support, approved the job criteria, and granted the permission to meet with the local union.

Island approached the local union officers, briefed them on the meeting with the District 17 officers, reviewed the scope of the project and the job criteria with them, and asked for their support and permission to ask for volunteers from the work force. Approximately three months passed before any action was taken by the local union to give Island Creek permission to select the needed miners for the project.

When permission was received, a letter asking for volunteers was posted on the bath house bulletin board for five days according to the standard contractural procedure. Twenty three miners volunteered for the project representing various ages, work backgrounds and abilities. The work record of each of the volunteers was reviewed to select two miners who met the requirements of the project.

Of the two men selected, one was 26 years old, had two years underground mining experience, and was a qualified roof bolter, shuttle car operator, and shot fireman. The other was 40 years of age, had 20 years underground mining experience, and was qualified to operate the loader, shuttle car, coal drill, roof bolter, and cutting machine. Both men had excellent work records and after discussing them with the supervisory personnel at the mine the men were notified of their selection.

The younger man was assigned to the project to assist in modifying the mining equipment to receive the life support system and to perform other duties in the project test office. The second man was assigned to the project when the equipment modifications were complete and the equipment was ready to be taken underground to establish the test face.

The following is the letter that was posted on the bath house bulletin board:

A T T E N T I O N

As of this date, December 31, 1971, the management of Island Creek Coal Company is asking for volunteers to participate in an experimental project to be conducted at this mine.

Qualifications will be minimal, but final personnel selection will be made by management and according to project requirements. At present the project is anticipated to run for a minimum of six months, with further testing to continue only if this phase proves feasible.

This is strictly a volunteer operation. Any personnel selected will be expected to return to their present jobs pending completion of the project, with their present rate of pay, and with no loss of seniority. However, while participating in the project, personnel will receive top rate of pay as outlined by the 1971 UMWA contract. In addition, testing will be done on the day shift for the entire length of the project.

If you have any interest in volunteering for the project, please sign your name in the space provided below.

Thank you.

SECTION VIII

EQUIPMENT MODIFICATIONS

Each piece of mining equipment for the project was delivered exactly as though the machine was to be used in a standard mining operation. No special modifications were made to the machines before they left the factory. At the time the equipment was ordered, the anticipated need for the machinery at the mine was such that the project was better served if project personnel would modify and install the life support units on the equipment at the mine. The two major difficulties encountered when mounting the life support gear was obtaining an electrical power supply for each unit and finding space available for attaching the life support units to each machine.

The life support unit operated at a different voltage than was normally available on the mining machines. The air conditioning unit, or chiller, required a 115V AC source, and contained a 115V AC/24V AC transformer which in turn supplied the 24V power for the rebreather. If a 115V AC power supply was available for the air conditioning unit, the rebreather power supply would be solved at the same time.

Each piece of mining eqipment had either a 440V AC or a 250V DC source available for driving the life support units. Ehe roof bolter, coal drill, cutting machine, and loading machine all operated on 400V AC, while the shuttle car operated from a 250V DC source. To obtain the 115V AC from the alternating current machines, additional wiring connected to the 400V AC line on each machine was required. This line must be energized whenever the machine was energized to allow the life support unit to operate even when the machine was sitting idle and nost just when the machine was actively working. This meant that each machine's power supply be taped directly from the electrical panel.

It was realized at the time that whenever this was done the permissibility of the machine would be destroyed unless the proper modification procedures were followed. This would greatly increase the cost of these changes and since the life support system was not permissible, the additional expense did mot seem justified. If the nonpermissible life support system could be used in the mine, there was no need for the mining equipment to be permissible. The wiring changes were made in such a manner that the minning machinery could be readily returned to its permissible rating with a minimum of effort. In addition, the Pond Fork operation is a nongassy mine and adequate rock dust was applied, thus greatly reducing any fire or explosive hazards. In general, the modifications to the machines were minor and would not incur any hazard to the mine personnel. The modifications were made knowing that though the equipment would be nonpermissible it would still be safe to operate at the test face. An inspection by the USBM personnel confirmed this and permission

was given to move the equipment to the underground test site.

To provide access to the 440V AC in the electrical panel, a hole was drilled through the panel cover plant to permit a 14 gauge, three conductor, 600 volt cable to pass through. This cable ran from the panel to a 1 KVA transformer where the power was reduced from the 440V AC to the 115V AC needed for the air conditioning unit. After leaving the 1 KVA transformer the 115V AC terminated at a single grounded outlet located near the air conditioner and easily accessible to the operator. The operator could plug in the air conditioner and rebreather whenever he so desired.

The shuttle car presented a little different installation problem as it operated on 250V DC and the rebreather operated on 24V AC power supplied from a 115V AC/24V AC transformer in the air conditioning unit. Here is was necessary to find a means to change the direct current to alternating current, or to find another way of using the direct current to operate the rebreather. A special air conditioner operating on 250V DC was purchased for use on the shuttle car and unlike the mechanical air conditioning unit, it did not provide the 24V AC power to operate the rebreather. A separate power supply for the rebreather was required. A small 1 KVA motor generator set was installed for this purpose. The 250V DC drive motor operated a 115V AC generator which supplied power to a 115V AC/24V AC transformer which in turn supplied the power for the rebreather. The motor generator was wired directly to the electrical panel and energized using a cut out switch located near the panel. The air conditioning unit was not an electrical wiring problem since it was a special unit designed to operate on a 250V DC power supply and was wired directly into the machine's electrical panel.

While the electrical hook-up of the life support units had its own special problems, even more troublesome was the attachment and location of the life support gear on the mining machines. The specifications for the air conditioner and the rebreather required that neither be more than 12 inches in height. The life support gear as delivered met these requirements, however in mounting these units it was impossible to keep them out of the operator's way and clear of the coal rib and mine roof.

The following is a breakdown of the problems associated with each mining machine:

Loading Machine - Joy Model 14BU10-31BH

The loading machine is mounted on rigid tracks and pivots at a point somewhat near the geometric center of the machine. The particular type of mount for the rebreather and chiller required that the electrical gauges, i.e., the wattmeter, ammeter, voltmeter, and hourmeter, be removed from the machine. The air conditioning unit was mounted in its place just in front of the operator on top of the machine. The rebreather was mounted to the rear of the operator and over the rear tram motor. This placed both the units in precarious positions since the loader pivoted in the manner described. On a rise in the bottom the pivot was such that the units could be crushed between

the machine and the roof. This did happen with one unit as the operator was backing the machine to the top of a small rise. While the rebreather case was destroyed, the rebreather continued to operate and the operator had no difficulty disengaging himself from the rebreather. The location of the air conditioning unit was far enough forward to prevent the unit from being crushed in the same manner as was the rebreather.

The only other difficulty found with the life support system mounted in the manner described was a problem of visibility. The operator at times had some difficulty seeing over the unit to properly position the machine to load a cut of coal. The last shuttle car or cleanup car was difficult to load since the operator could not always see over the top of the machine to pick up the last few scraps of coal.

Cutting Machine - Joy Model 15RU-3A

The cutting machine contained enough space to mount the rebreather below the height of the machine. The air conditioning unit was mounted opposite the operator's normal position on the left deck of the machine. The rebreather was mounted just above the left hand deck in front of the operator. Connection between the two units was made with one-inch rigid copper tubing. The rebreather location was somewhat less than ideal since it extended beyond the width of the machine. The operator had to be careful that the machine remained clear of the coal rib at all times. Visibility was no problem.

Coal Drill - Galis Model 460

All of the roof drill controls were set on the left side of the roof drill so it was necessary to locate the air conditioner and rebreather as close as possible to the operator's controls. The operator also had to be able to set temporary jack posts to support the roof while he drilled and inserted the roof bolts. The air conditioning unit was mounted to the rear of the left side of the operator's deck, with the rebreather mounted above the air conditioner on top of the machine. These mountings proved ideal for the machine's operation since the overall height of the machine was low enough to maintain adequate clearance between the life support units and the mine roof.

Connection between the units was made by using rigid copper tubing one inch in diameter with sweat soldered couplings.

Shuttle Car - National Mine Service Type 48-S18-36AL

The shuttle car presented a special problem since space available for mounting any additional equipment was extremely difficult to find. A specially designed air conditioning unit plus a motor-generator to provide 115V AC from the 250 V DC available on the machine had to be installed. Space available dictated that the rebreather be mounted atop the shuttle car between the two drive wheels forward of the operator's deck. The thermionic air conditioning unit was more compact than the air conditioners mounted on the other machines;

however, it still presented problems on mounting on the shuttle car. The only space available was in the area forward of the operator's deck adjacent to the electrical panel. The unit consisted of two components--an electrical power supply and the cooling unit. To utilize the space available, the air conditioner had to be mounted on top of the power supply next to the electrical panel.

Rigid connections between the chiller and rebreather were not possible since the various hydraulic lines on the shuttle car made it impossible to install rigid tubing. The one inch plastic tubing used for the tethers was used to connect the two units together.

The motor-generator was bolted directly to the machine behind the operator's deck on the side of the conveyor and supplied 115V AC to the 115V AC/24V AC transformer mounted beside the rebreather.

These locations had some effect on the visibility of the operator but not enough to prevent the safe operation of the machine. The major hazard here was the possibility of crushing the rebreather between the machine and the roof. Clearance at this point averaged around six inches, thus making it necessary for the operator to exercise extreme care.

SECTION IX

MINER TRAINING
MINERS' LIFE SUPPORT SYSTEM

One miner assigned to the project was used to adapt the chiller and rebreather to the mining equipment, and to assist in setting up the office building and in constructing storage racks and workbenches, etc. Only one miner was initially assigned to the job as it was felt there would not be enough work to keep two men busy. All preliminary testing was done using this one miner. The second miner was assigned to the project after the equipment had been modified and just prior to taking the equipment underground.

After completing the modifications to the mining equipment to receive the chillers and the rebreathers, the remaining life support systems were received from MSA Research Corporation and an additional life support suit to fit the second miner was received from Arrowhead Products Corporation. The suit designed to fit Mr. Turner fit the first miner. The preliminary draft of the Operation and Training Manual was given to the miner for his review and education. Several sessions were held in which the system was thoroughly explained to him and all questions were answered. The hazards of using compressed oxygen and the effects of carbon dioxide and carbon monoxide on the body were reviewed so that he was thoroughly aware of what to expect from the system and how it could affect his systems. He assisted in servicing the units and in the modifications to the rebreathers made in the field. He reviewed the Operating and Maintenance Manual and was thoroughly indoctrinated into the operation and maintenance of the rebreather.

On several occasions, he donned the suit and the life support system was activated to familiarize him with the system--how it felt and how it operated. He practiced changing from the portable uncooled mode to the fixed cooled mode. This was done to develop confidence in the system, mainly the quick disconnect valves in the tethers. When changing tethers, these valves maintained the pressure in the suit. However, air flow was interrupted until the hookup was completed. This created no problem with either of the miners. Different start up procedures were tried until the approved start up procedure, as indicated in the training manual, was developed. See Appendix A.

Several tests were conducted with the miner so that he could experience having the suit sucked down and clinging to him caused by a leak in the discharge side of the blower or being over inflated caused by a leak on the suction side of the blower. He was made aware of the action of the oxygen regulator and to recognize when it was not operating properly. Every effort was made to make him totally aware of how the system would react under different conditions. There was no hesitancy at any time on the part of the miner to don the suit or to experience these different emergencies. He was

interested in all aspects of the system and was eager to learn.

During this training period, no effort was made to develop a highly technical program and the training period was relatively short. Every effort was made to teach and learn by experience. Both miners were anxious to learn and showed no fear for the system. They learned rapidly and were able to handle all situations that might develop.

During this training period, several items of the life support system were further resolved. The testing with the leotard stretch garment was conducted with considerable satisfaction.

The training and start up procedures were developed utilizing the first miner assigned to the project. He had the advantage of a longer training period and experiencing some of the pitfalls while developing these procedures. As a result, he was well-versed in the equipment and its use. The second miner was assigned to the project after the development of these procedures and approximately two weeks before the equipment was to go underground. He was trained as described above and had no problems operating the life support equipment.

Slight modifications were made to the life support system at the mine and the final system as tested in the mine can best be explained pictorially. The following figures constitute the Miner's Life Support System that was tested in the mine.

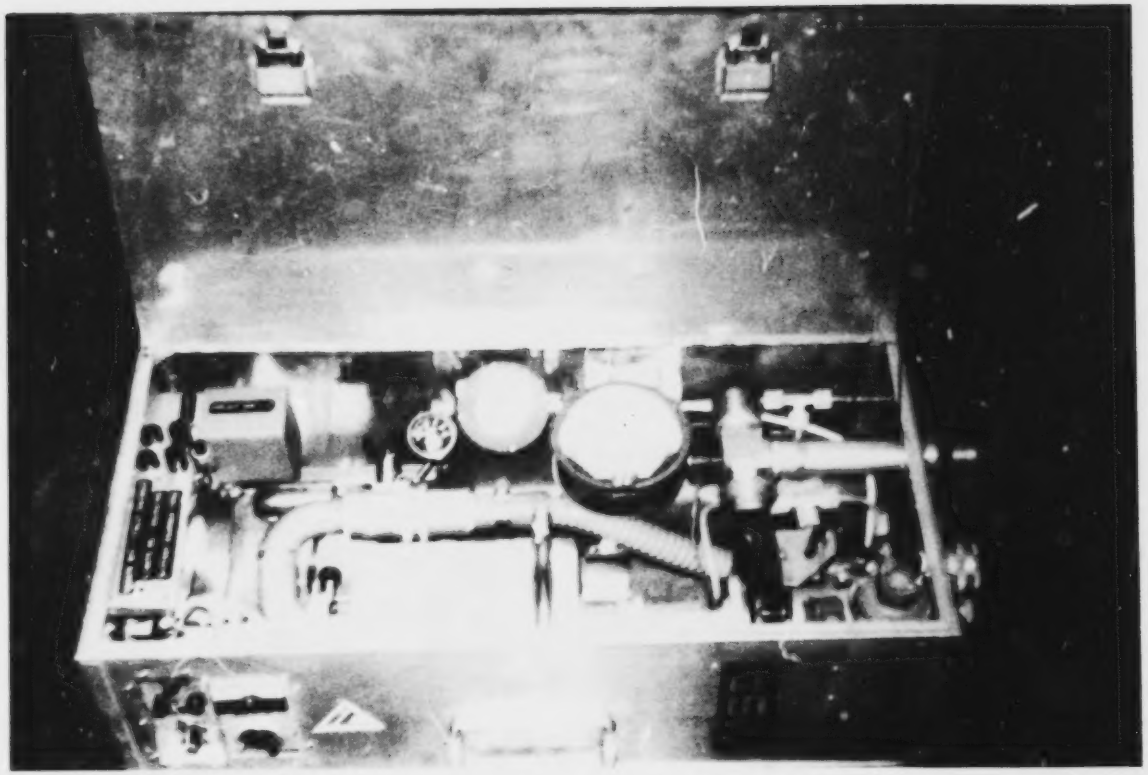
Figure 7 - Mine Personnel Rebreather - modified - shows the rebreather used in the mine. Note the large dial in the center. This is the pressure gauge indicating the in-suit pressure. The 24V AC external power plug can be seen at the right of the unit in the "plugged-in" position.

Figure 8 - Mine Personnel Chiller-Condenser-A shows the mechanical chiller-condenser supplied by MSA Research Corporation. The chiller can be seen at the left of the picture. Note the connections for the tethers, the drain valves, and 24V AC power cord. The unit on the right is a hermetically-sealed refrigeration compressor and the small square unit in the center is the temperature control.

Figure 9 - Mine Personnel Chiller-Condenser-B shows the thermionic chiller purchased for use on the shuttle car. The 250V/96V DC power converter is seen at the left of the picture. The unit on the right is the chiller-condenser. At the right of the chiller-condenser, you will note the inlet tether connection and on the left, the exit tether connection. Visible also are two of the four minifans used to cool the unit.

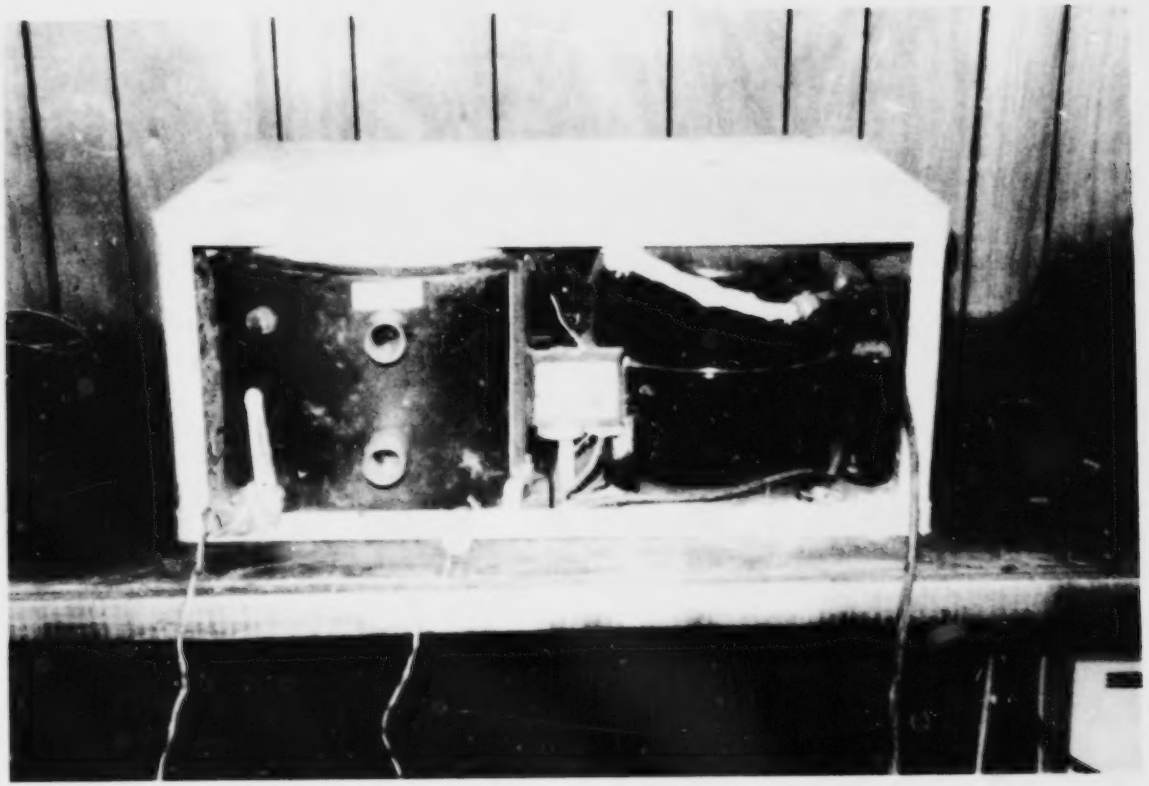
The rebreather and the cooling unit are the heart of the life support system. They provide the cool air required for the miners' comfort. These, when connected via tethers to the life support suit, complete the life support system.

The following figures show the various components that make up the life support suits.



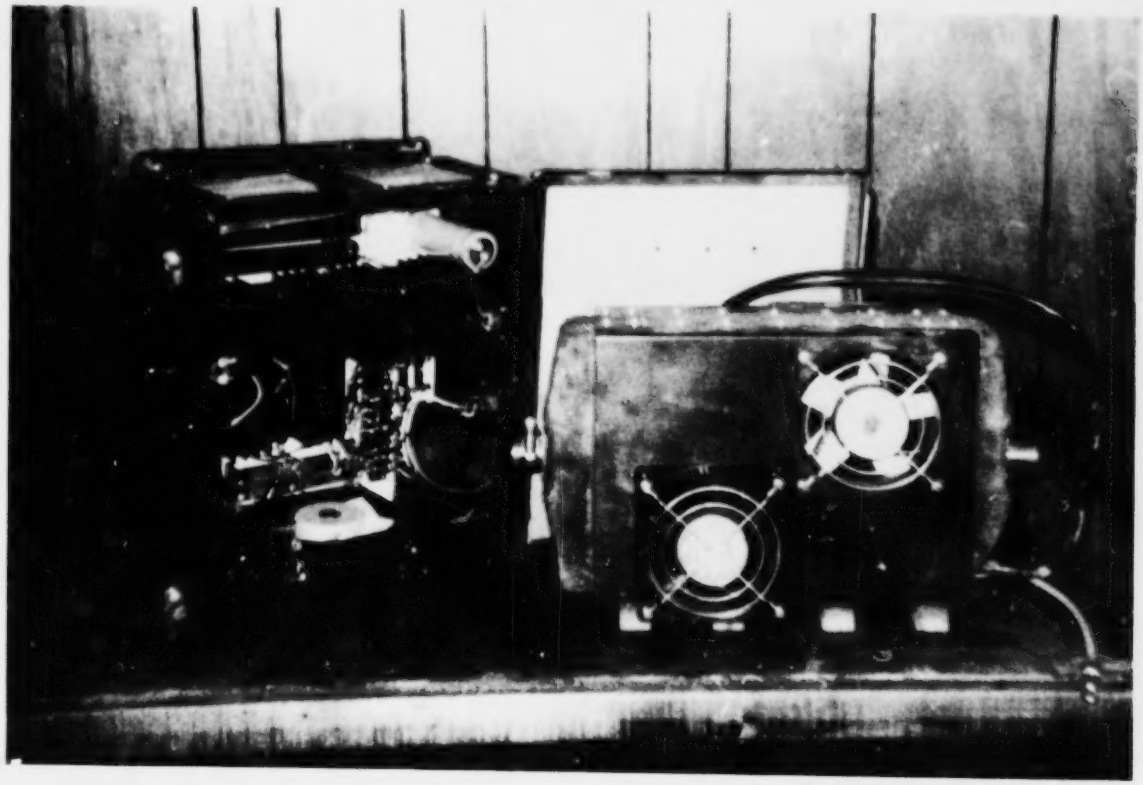
Mine Personnel Rebreather (MPRB)

Figure 7



Mine Personnel Chiller-Condenser-A (MPCC-A)

Figure 8



Mine Personnel Chiller-Condenser-B(MPCC-B)

Figure 9

Figure 10 shows the Mine Personnel Undergarment (MPUG) worn next to the skin. This is a standard cotton knit, long sleeved, long legged set of underwear. Its primary purpose is to absorb perspiration, to provide uniform cooling of the body, and to protect the arms and legs from the chafing of the gas-tight suit.

Figure 11 - Shows the front of the gas-tight Mine Personnel Suit (MPS). Note the storm cuffs at the wrists and on the upper leg. Note also the tether connections on the right breast and the helmet mating ring.

Figure 12 - Mine Personnel Suit (MPS). Note the across-the-shoulders zipper which is the entrance to the suit. This is a standard air-tight zipper presently used by NASA for their launch support personnel.

Figure 13 - Shows a front view of the Mine Personnel Stretch Garment (MPSG). When compared to the front view of the Mine Personnel Suit, note the ability of the stretch garment to confine the Mine Personnel Suit. Note also the opening for the tethers and the zipper for ease of donning.

Figure 14 - Mine Personnel Stretch Garment (MPSG). This is a side view of the stretch garment. When compared to the side view of the Mine Personnel Suit, note how the stretch garment confines the suit.

Figure 15 - Miner's Life Support System (MLSS). This is the complete life support system showing the miner completely dressed and carrying his helmet. Note the use of standard coveralls and the miner's belt and the standard miner's lamp mounted on the helmet.

Figure 16 - Miner's Life Support System (MLSS) shows the complete miner's life support system in the portable mode. The rebreather continuously circulates air through the tethers to the miner and back to the rebreather, providing all his breathing requirements. No cooling is provided in this mode.

Figure 17 - Miner's Life Support System (MLSS). This shows the position of the various components in the rebreather case when in the portable mode.

Figure 18 - Miner's Life Support System (MLSS). This shows the miner with the life support system in the portable mode ready to enter the mine. Note on the helmet just behind the visor a little black dot. This is where the communications cord passed through the helmet.

After reviewing these figures, note that standard garments were used wherever possible; that is, standard underwear, standard stretch garment, and standard coveralls were used. The assembled life support system worn by the miner looks like it belongs in the mine and should be totally accepted by the miners. This is the system that was tested in the mine and proved satisfactory.

The Operating and Training Manual for the life support systems and the Operating and Maintenance Manual may be found in Appendices A, B, C, and D.

Mine Personnel Undergarment (MPUG)

Figure 10

Mine Personnel Suit (MPS)

Figure 11

Mine Personnel Suit - MPS

Figure 12

Mine Personnel Stretch Garment (MPSG)

Figure 13

Mine Personnel Stretch Garment (MPSG)

Figure 14

Miner's Life Support System (MLSS)

Figure 15

Miner's Life Support System (MLSS)

Figure 16

Miner's Life Support System (MLSS)

Figure 17

Miner's Life Support System (MLSS)
Ready to Enter the Mine
Figure 18

SECTION X

TEST SITE

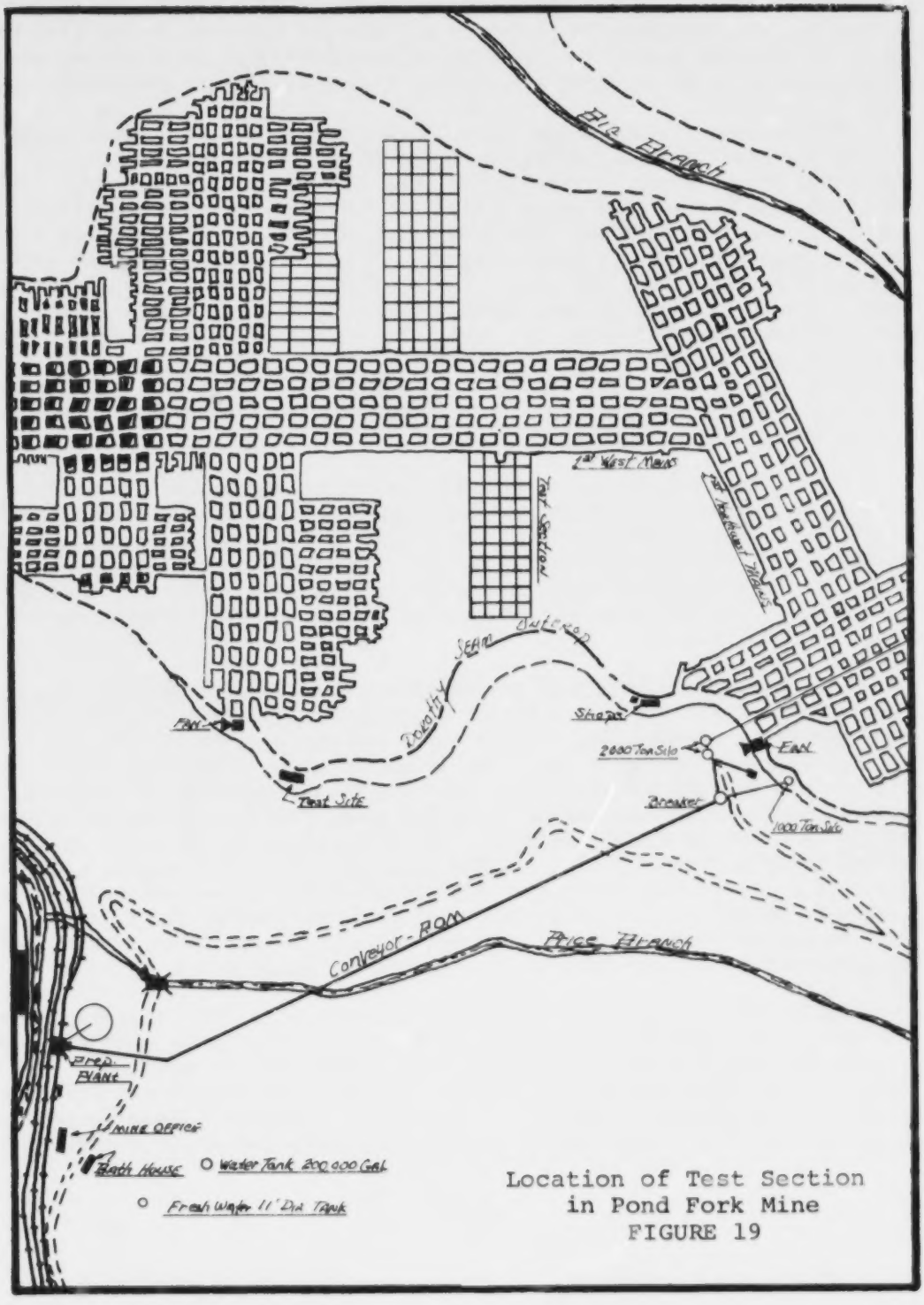
Island Creek Coal Company's Pond Fork Mine, located approximately 14 miles east of Madison, West Virginia, along West Virginia Route 85, near the small town of Kohlsatt, was chosen as a suitable location for the project tests. The mine began operation in April, 1970, with an expected annual production of 950,000 tons per year. Two separate seams of coal are being actively mined. They are known as the Dorothy Seam and the Number Five Block Seam. Both seams are being extracted through drift openings by conventional room and pillar methods of mining. They are above drainage, with the Five Block Seam located above the Dorothy Seam. All coal is removed from the face areas by belt conveyors to the outside where it is stored in concrete silos before being transported and processed through the preparation plant located on the valley floor.

This site was chosen for several reasons. Preliminary investigations determined that this mine had a better than even chance for the production of acid mine water drainage. It was nongassy and had an average working height at the mine faces of 48 to 60 inches. The Pond Fork mine was one of Island Creek's newer operations and met all of the desired conditions for the project.

The Phase II office was built on the Dorothy level at the latter extent of the outcrop shown on Figure 19. This location was the closest to the main mine portal that the building could be placed. Several weeks of grading and slope stabilization had to be done before a reasonably safe foundation for the office could be constructed. Several drainage ditches and drain pipes had to be installed before constructing the building. After the site had been stabilized, the building was constructed by a local contractor.

Since some testing of the mining equipment was required at the office building, a power supply to serve the 500 KVA underground mine power center had to be installed along with the lighting and heating transformer to supply power to the Phase II office. Approximately 900 feet of right of way had to be cleared and a number of poles installed to run the high voltage lines up the hill from the coal preparation plant in the valley to the project office. Water and sewage treatment facilities were purchased and/or installed but never placed into operation due to pending labor problems at the mine. As a result, no facilities were installed for showering, washing, or otherwise. However, all sewers, floor drains and ventilation lines were installed.

The particular test area in the Dorothy seam was chosen because it had the required seam height and was readily accessible to the surface facilities. Several possible test sites were reviewed and the area selected for the test face was located approximately 2500 feet from the main portal in the First



Location of Test Section
in Pond Fork Mine
FIGURE 19

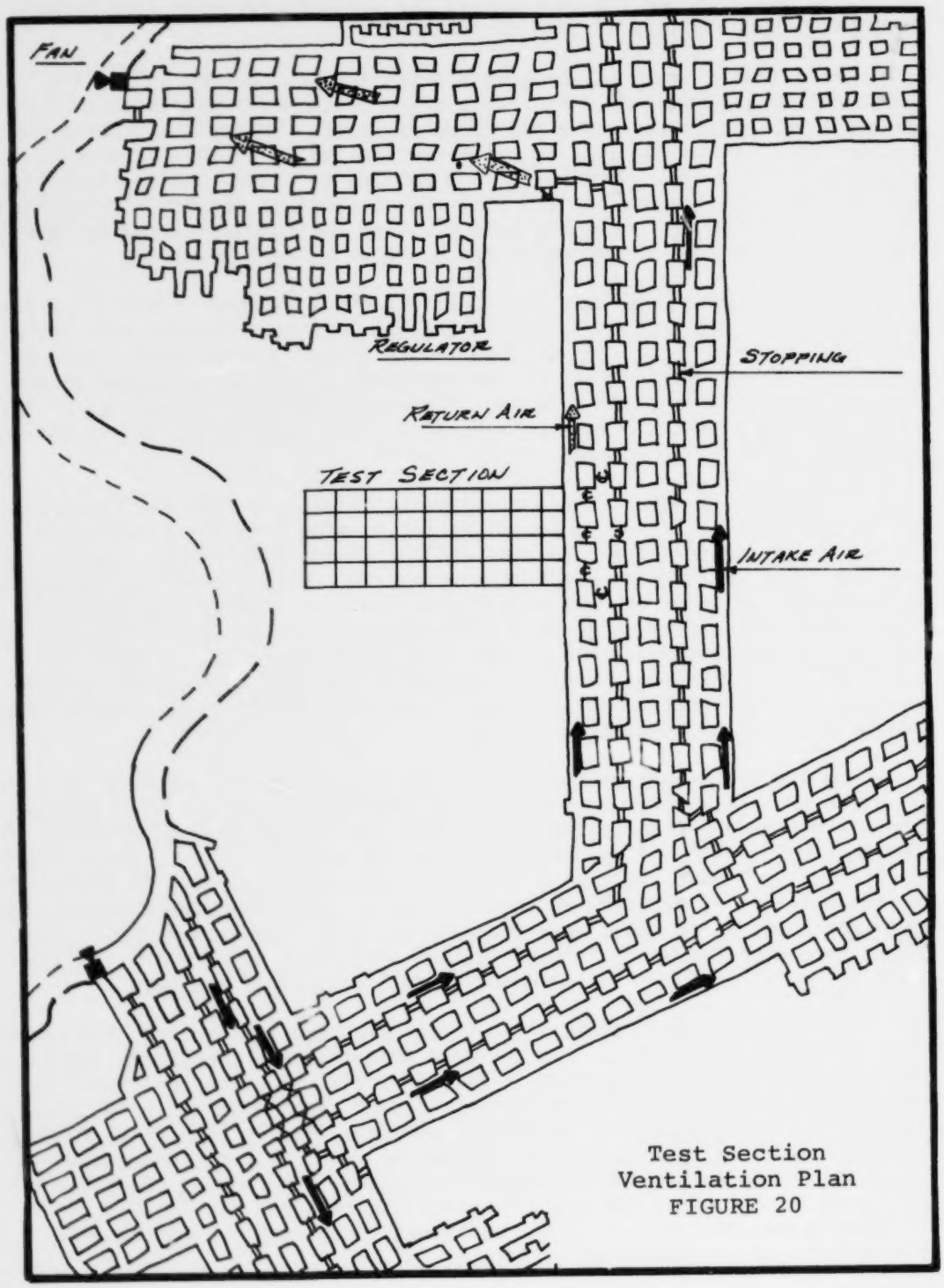
West Mains area of the mine. There was another active working section in the area in by the test face. This required that the test section be placed on a completely separate split of air, i.e., the air supplied to the test section would be directed toward the fan with no possibility of reaching any other working faces in by the test areas. See Figure 20 for the ventilation plan.

The necessary ventilation controls to direct the airflow were constructed during the miner's annual vacation period so as not to interrupt normal operation of the mine. Visits to the area before the airflow change indicated that the area was in a relatively neutral air split and that conditions were ideal for the test section. The area was clear of obstructions, had a firm bottom, good top, and was reasonably dry. These conditions changed after the air was directed across the area. The section's proximity to the outside meant that there would be considerable sweating of the top as warm moist air was cooled as it passed over the area. The resulting moisture caused the top to slake considerably causing roof failure between the roof bolts thus loosening the roof support in the area. As a result of this, considerable time was required to clean up the area and make it safe again before any mining operations could begin.

This clean up work was delayed as the mining equipment purchased for the project was required to do the job and permission had not been received from the U. S. Bureau of Mines to take this nonpermissible equipment underground. Immediately following the receipt of the permission to move the machinery underground, all equipment was moved to the face area using the local mine personnel. This was done on a weekend so as not to interrupt the normal mining operation.

Following the movement of the equipment underground, several days were required to repair the damage to the equipment caused when dragging it to the work face. The loading machine cable had to be detached from the machine and spliced, and the cable guard had to be replaced. The operator's seat bracket was twisted and the cable chain guard was torn from the machine. The 500 KVA power center was hooked up in the wrong heading and had to be moved and reinstalled in another heading. The drive chain on the cable takeup reel on the shuttle car was broken and had to be spliced. The cutting machine did not have a low voltage cable couplings attached and it was necessary to splice a coupler to the machine cable before it could be used at the test face. This same condition applied to the roof bolter. All of these repairs had to be completed before any type of face operations could begin.

Following the equipment repair the cleaning up operation began. Using the loader and shuttle car, project personnel cleaned approximately 480 feet across the face area for a length of four breaks for two headings. The material was dumped out by the face in the old works since there was considerable rock and no way of loading it on the belt conveyor. Cleaning operations included the final shoveling of all ribs to remove coal or fine dust.



Test Section
Ventilation Plan
FIGURE 20

Following the cleaning the entire area was machine- and hand rock-dusted, requiring approximately 15 tons of rock dust.

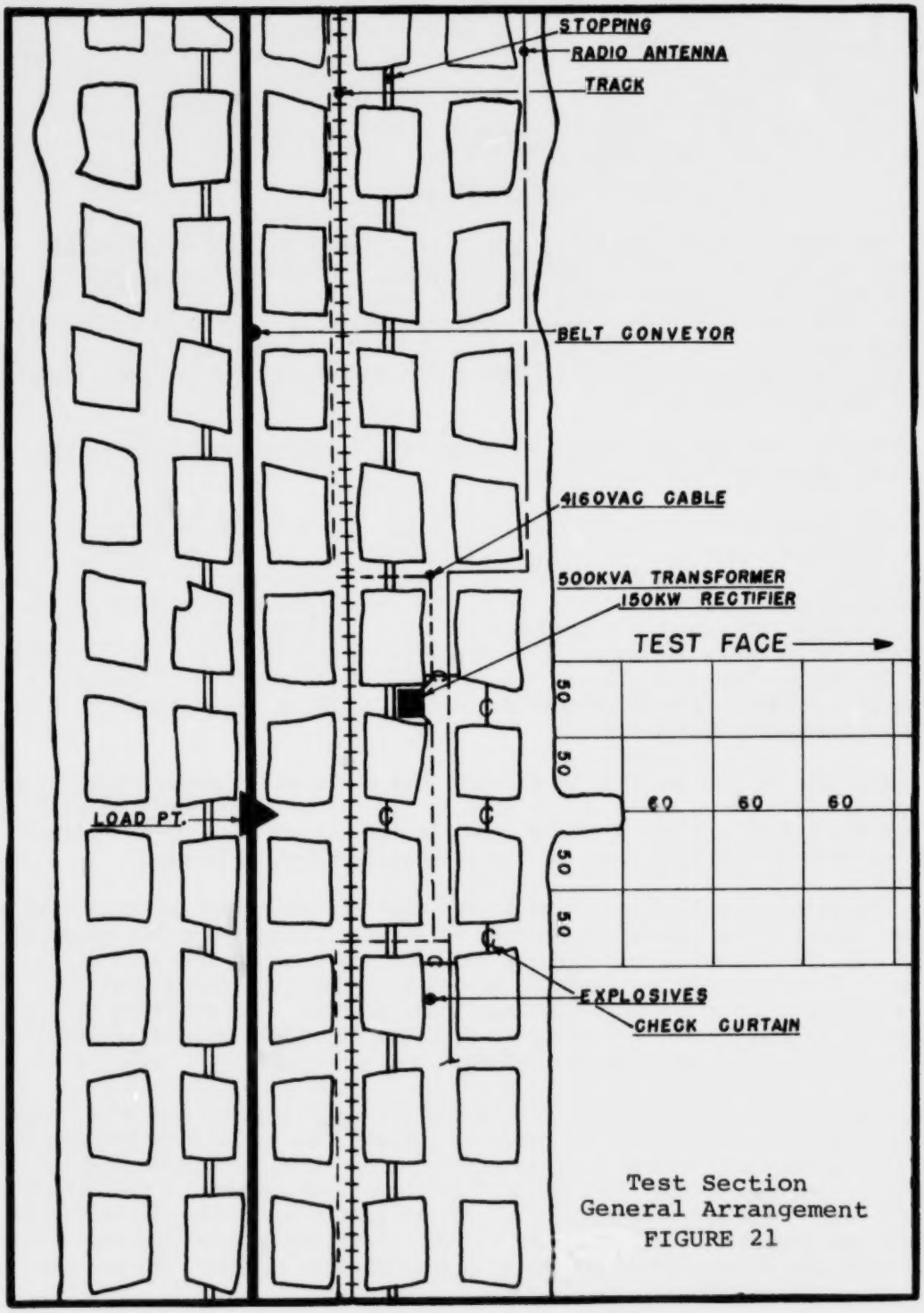
While initial roof supports were installed in the area before any personnel were allowed to work, the slaking of the roof had loosened many of these roof bolts and these had to be replaced. In addition nearly 200 timbers were set in the area to bring the section up to the standards required by mine law. Roof bolts were spotted as needed and any extensive bolting was done to the standard five foot centers as required in the mine permit. Timbers were set along both sides of the roadway narrowing them to 16 feet wherever the untimbered areas exceeded 20 feet in width.

After securing the roof, the ventilation was changed to bring the entire airflow across the working faces rather than letting a portion pass through the first heading out by the working face. Check curtains were placed at both ends of the section and fly curtains were installed as needed to air lock the air passing across the face and to prevent the short circuiting of the air. Airflow across the face was averaging more than 15,000 CFM at the intake and 12,000 CFM in the returns.

In order to maintain haulage to the belt conveyor from the face area, a track crossing for the shuttle car was built using 3 inch x 6 inch x 14 foot planks installed perpendicular and parallel to the mine track. The area under the track was shoveled to the bottom rock base. Planks were laid perpendicular to the rails for the entire width of the mine roadway and ballasted. Two planks were placed underneath each mine rail and spiked to the rail using the six inch spikes available at the mine. Additional planks were laid parallel to the track both between the rails and outside to give a smooth crossing for the shuttle car. These planks were nailed to the planks underneath to complete the track crossing.

The limited height of the area at the track crossing required that the existing trolley wire be countersunk and guarded to provide safe passage of the mining equipment under the wire. This was accomplished by drilling 23 one foot holes into the roof the entire width of the haulway. Following the drilling, two 1 inch x 8 inch x 14 foot planks were installed on each side of the holes using standard 30 inch roof bolts and timbers were set between the roof bolts. The holes were then charged and fired in a ten shot, ten shot, three shot sequence. The resulting roof break allowed the trolley wire to be lifted above the surrounding roof and out of the way.

Following the completion of the track crossing and trolley wire countersinking, the loader and shuttle car were able to cross the tracks and clean the haulway to the belt conveyor. This area also required additional roof bolting and timbering. A side dumping loading station at the belt conveyor loading point was installed by project personnel during a shift when the belt conveyor was idle to complete the section set- up. All of the foregoing work was required before any of the Phase II testing could begin. Considerable time was spent in preparing the section, resulting in additional delays and shortening the test period of the equipment. Figure 21 is the general arrangement of the completed test face.



Test Section
General Arrangement
FIGURE 21

SECTION XI

COMMUNICATIONS

The "leaky cable" communications system from Motorola Communications System, Incorporated, recommended in the Phase I report was purchased for use on the project (see Appendix G). This included a VHF base station or transmitter, four portable high frequency FM transceivers, one remote console type transceiver, and a remote monitoring station. The antenna cable was purchased directly from the manufacturer. These units were installed and comprise the basic communications system.

Radioear Corporation supplied the hearing aids that were used by the miner to sense the in-mine noise.

The portable transceivers contained a push-to-talk switch to press whenever a message was being sent. Since the miner was inside the helmet, some other means of operating the transceiver had to be provided. A radio receiver and microphone had to be mounted inside the helmet and a means provided to automatically activate the microphone whenever a message was sent. A voice-operated relay (VOX) was supplied by Motorola to do this. This unit clamped onto the transceiver and plugged into a receiver and microphone located in a standard hard hat. The microphone and receiver had to be remounted in the helmet supplied by Arrowhead.

The hearing aid supplied by Radioear was wired to a standard hearing aid ear plug. This setup could not be used in the helmet as it would be difficult to don the helmet and the pressure from the ear cup would be uncomfortable over an extended period. Another type of receiver was required.

The helmet supplied by Arrowhead was equipped with foam ear cups with a molded recess for a standard telephone receiver. To use any other receiver would require a special mold for the ear cups and increase the cost of the helmet. Both Motorola and Radioear agreed that their equipment would operate satisfactorily using the standard telephone receiver. The Motorola service center in Pittsburgh was contacted to make the necessary changes to adapt both the hearing aid and radio to the helmet.

One of the first problems faced was how and where would the wires pass through the suit to connect the radio to the ear receiver. A receptacle at the left breast area of the suit was tried. The wires ran inside the suit to a plug at the neck ring. To complete the in-suit connection, a plug in the helmet would be plugged into the plug at the neck ring, after the helmet was put on and before the neck ring was closed. A mating plug on the radio would plug into the receptacle on the suit to complete the system. The receptacle

on the suit created a pressure point that was very annoying and the plugs at the neck ring were extremely difficult to mate. As a result, alternate systems were tried.

The most acceptable system proved to be a connection located behind the right ear on the helmet. Arrowhead developed a special fitting that permitted the wires to pass directly through the helmet without the need of plugs. Silicone rubber was used to make an air-tight seal at this point. Two sets of wires exited the helmet at this point. One set was for the radio and microphone and the other for the hearing aid. Suitable mating plugs were provided to complete the system.

Inside the helmet, the hearing aid was wired to the receiver in the right ear and the radio was wired to the receiver in the left ear. Figure 22 is the wiring diagram for the helmet. Two different types of microphones were tried. A boom microphone was located on the helmet ring in front of the mouth in two helmets and a bone conducting microphone was located in the helmet support straps at the back of the head in the other two helmets. This enabled the miner to hear mine noise through the hearing aid in the right ear and radio messages in the left ear. To transmit all he had to do was to begin talking and the voice operated unit would close and the message would be transmitted. All helmets were wired in this manner.

Installation

The outside communications components, the remote console transceiver and base station, were located on the Dorothy Seam level of the Pond Fork mine. The base station was located at the mouth of the main mine portal and the remote station was placed in the mine shops. These units were connected by 570 feet of two conductor mine telephone cable. The remote transceiver was placed in the mine shops because there would always be someone present to receive messages. Telephone cable was installed from the shop to the Phase II office for possible relocation of the remote transceiver. The connection was never made since all needed contacts were made through the shop.

The base station or transmitter was mounted on the rock dust storage silo located at the mine mouth. 440V AC power was supplied to the unit from an existing transformer in the area. A small 440V AC/115V AC transformer was installed adjacent to the transmitter to reduce the power to 115V AC for the transmitter. Power was maintained to the base station at all times in order to keep the unit at normal operating temperatures and moisture free. From the base station a length of co-axial cable ran to the balun or transition unit for connecting the co-axial cable to the underground antenna to provide a balanced signal, and mated to the antenna cable in the mine.

To test the system the antenna cable was placed in the track heading because it was felt that communications would be better maintained in this manner. Traffic through the area was more frequent and the cable could be better observed for easy troubleshooting and maintenance.

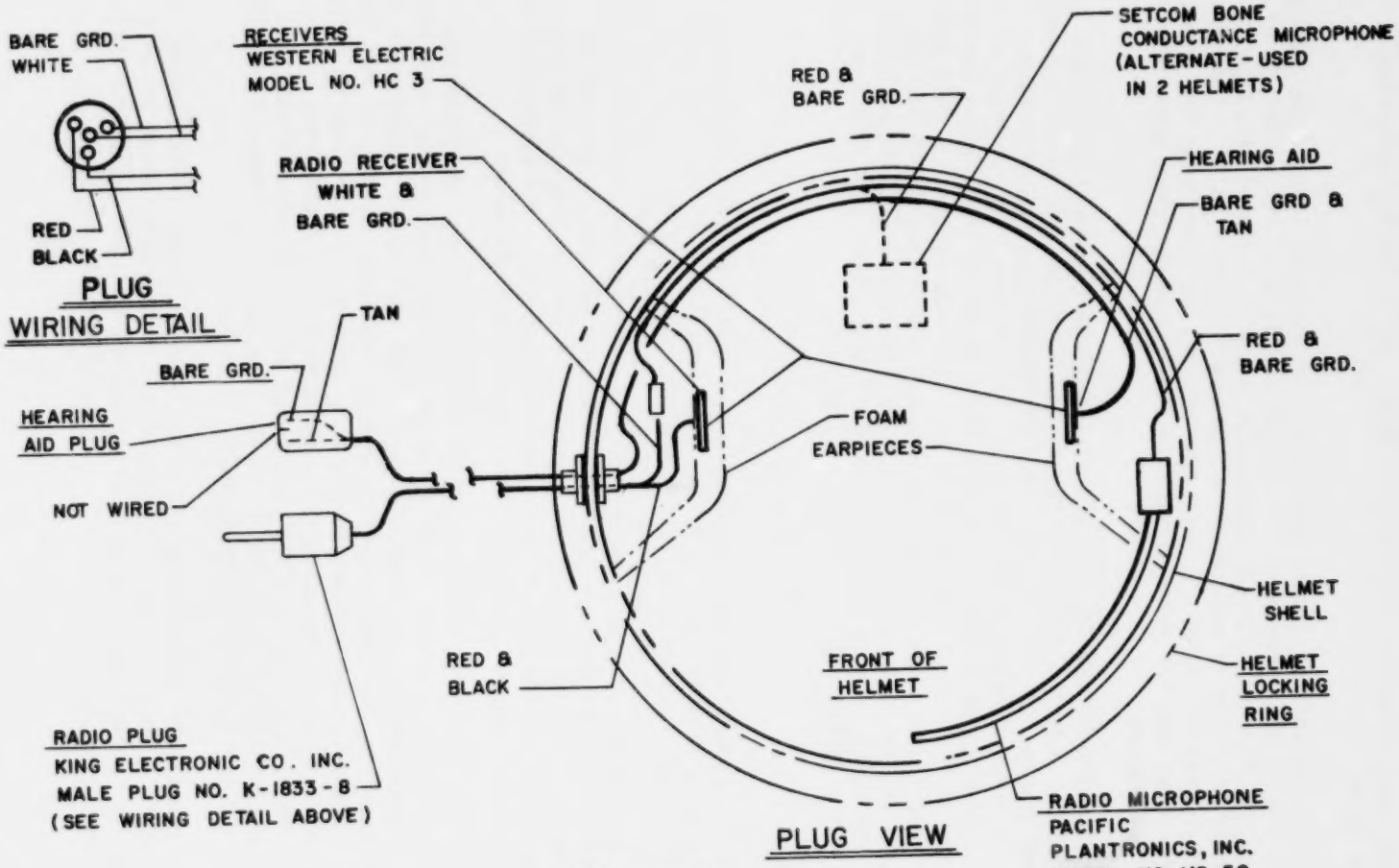


FIGURE 22
COMMUNICATIONS WIRING DIAGRAM
MINERS LIFE SUPPORT HELMET

The recommendations at the time the cable was installed were that the antenna had to be placed a minimum of eight inches from the mine roof and coal rib. This was recommended in order that the cable could give the proper operating characteristics. The cable was hung using 21 inch heavy duty Panduit plastic tie straps either nailed to a mine timber or attached to an existing roof bolt. Care was taken for the first few hundred feet to keep the cable at the proper spacing and away from any hazards. The cable was then allowed to contact both the roof and the rib at several different points. This supposedly would destroy the radiating ability of the cable. Subsequent testing proved that touching the roof or rib had no effect on the cable's performance.

The antenna was able to pick up signals from the transceivers through the limestone block stoppings running parallel to the entire length of the antenna. For this reason, the antenna position was moved from the track heading to the first section heading and hung for a distance of approximately 80 feet from the first working face on the test section. The antenna was then taken to the first heading out by the face of the test section and hung for the length of the section for a distance of about 350 feet.

The height limitations of the equipment and roof made it virtually impossible to keep the antenna at the specified minimum distance of eight inches from the roof and ribs. The eight inches would not provide sufficient clearance to keep the cable from being snagged by the equipment. Since the earlier experience had shown that the proximity of the cable to the roof did not hinder communications, the cable, hanging across the face, was tied as close to the roof as was possible. The resulting performance further confirmed that this method of hanging the cable did not hinder communications.

Shortly after installing the antenna, a roof fall buried the antenna for approximately 80 feet. A rock fall of this type was thought to interrupt communications beyond this point. There appeared to be no loss in signal strength and communications were maintainable beyond this point throughout the project with no difficulty.

In hanging the antenna cable, it was necessary to splice it on three different occasions. One splice was for the connection between the co-axial cable and the underground antenna and the other two along the length of the cable. The splicing procedure as outlined by the cable manufacturer was deviated from in actual practice. The procedure was lengthy and difficult to make and the materials used were difficult to work with. Cutting the plastic spacer for keeping the dielectric spacing constant was particularly difficult. The plastic insulation was difficult to cut and molding the spacer to hold the wire conductors required considerable time. To complete the splicing of the wires in the cable, a standard shrink type vulcanized splice commonly used in the mine was used to cover the splice. This gave the cable the strength and flexibility needed for good performance and provided the necessary moisture proofing.

The actual testing of the communications at the test face was very encouraging. No particular precautions had been taken during the installation of the antenna and little maintenance was required for any of the equipment once the installation was completed. Communications with the surface were immediate, time saving, and made with little difficulty. Portable to portable communications proved excellent for line of sight talk. The only difficulties arising when the distance between them was great enough to involve some roof and bottom rolls. Communications between portables was good in the section area for the length of 300 feet or so, but was greatly reduced whenever two lines of mine pillars were between them. Under these conditions, it was necessary to relay messages to the mine shop and back. Overall, the communications system installed proved to be invaluable when considering the time saved and ease with which the units allowed communication with the surface.

Some difficulty was experienced when trying to talk to the man while the machinery was running. The machinery noise made it difficult to hear incoming messages and on many occasions the miner did not realize he was being called on the radio until the machine was shut down. Some means of alerting the man to incoming messages is required.

The voice-operated relay system used to activate the microphone for transmission proved troublesome. In many cases, the first word or two of the conversation was lost due to the time delay required for the relay to operate. In order to satisfactorily use this system, it was necessary to clear your throat or activate the relay with some other meaningless noise. The relay also appeared to chatter and operate for no apparent reason when no messages were being sent. This was annoying and as a result the push-to-talk mode was used for most of the transmissions. This proved quite satisfactory and all future communications should be conducted in this manner.

The boom microphone presented some problem in that the location of the microphone in respect to the mouth appeared to be critical, causing the message to come and go as the man talked. It was difficult to reposition the microphone for best communications as the man could move his head inside the helmet. He would have to have his helmet on in the exact same position each time he wanted to talk. The bone conducting microphone did not have any of the problems associated with the boom microphone. Satisfactory communications were obtained at all times. The position of the microphone on the head and the amount of hair did not appear to affect its ability to perform. The bone microphone should be used for any future communications of this type.

The hearing aid enabled the man to hear the in-mine noises; however, it was difficult to sense the direction of the origin of the noise. Not only did the hearing aid amplify the in-mine noise, it also amplified the noise of the mining equipment. As a result, the volume control of the hearing aid was turned down, reducing the man's ability to hear other noises. No concentrated effort was made to evaluate this problem due to the limited testing performed and the precedence of other problems. A means must be developed to selectively dampen the background machinery noise while amplifying the other noises.

RECOMMENDATIONS

- Additional work is required to evaluate the performance of the radio and hearing aid and a means developed to receive both the radio and hearing aid in both ears.

- Directional hearing using the hearing aid is required to enable the sensing of the direction of noises.

- The voice operated relay system should be replaced with a push-to-talk button.

- The antenna cable should be of a more flexible design allowing more stretch and bend. Cold weather installation particularly aggravates this situation.

- Antenna cable should be of a type not requiring any minimum distances to be maintained from any underground structure, other than for safety reasons.

- A repeater type system would allow personnel to maintain direct communications with one another without relaying through the surface equipment.

- The cable should be rugged enough to withstand any crushing coming from either rock falls or from equipment running over it.

- The cable hangers used for installation should allow the cable to bend or flex whenever the cable is bumped.

- The spacers used in splicing the cables should be pre-cut for the proper dielectric spacing to provide more ease in installation.

- Whenever the cable is installed at a working face, it should be hung across the first line of breaks out by the loading point. This method will give full coverage of the face areas and minimize installation problems.

SECTION XII

IN-MINE TESTING
MINER'S LIFE SUPPORT SYSTEM

The many delays in the project limited the in-mine testing to a period of six weeks, whereas the original schedule called for six months of in-mine testing. The installation of the communications system was completed before establishing the in-mine test face and was used extensively while the test face was being readied for the test program. Once the test face had been established and met all the mining safety regulations, the testing of the life support system began.

The test face was located inside the adjacent mine approximately twenty five hundred feet from the main portal. Transportation to the test face was via the mine scooter. Figure 23 shows the two miners with their life support systems on board the mine scooter, ready to enter the mine. All personnel and equipment were taken into the mine in this manner.

There were no provisions in the project to provide a transport vehicle capable of transporting a completely suited man to the test face. The men therefore had to carry their helmets and rebreathers into the mine. Once reaching the test face, the rebreathers were mounted on the mining equipment, the tethers were connected to the suit and rebreathers, the helmet was donned and the system put into operation. This gave time to make the hookup and overcome any delays that might occur in the mine. On at least one occasion, this did present some problems. The heat built up in the gas-tight life support suit to the point where tests had to be cancelled because the miner had become overheated and developed a chill when the air circulation system was placed in operation. The delay caused by waiting for transportation to get into the mine and an additional delay in the mine due to mining equipment problems created this situation.

The second miner had been assigned to the project just prior to taking the equipment underground to develop the test section. Time was taken to train and educate him in the use of the life support system. On two or three occasions he put on the suit and was instructed on how to place the system in operation so that he understood the system and had no fear of it. His training was held to a minimum to determine the reaction of the man to minimum training and the confidence he might have in the system.

In order to familiarize each man with operating the mining equipment while using the life support system, each man was taken into the mine separately. All other project personnel observed the tests. The No. 2 miner was the second miner assigned to the job, but the first one to test his life support equipment at the test face. The first miner had previously demonstrated his

Miners Ready to Enter the Mine

Figure 23

capabilities using the life support system earlier in the project for a group of visitors.

The second miner suited up in the office and was driven in a truck to the mine scooter and taken to the test face. Here is was necessary to move some mining equipment around to position the first piece of equipment to be tested, which was the coal cutter. The helmet was placed on the deck of the cutter while tramming and when passing through one of the curtain barriers, the helmet was brushed off the cutter and underneath the wheel. The visor popped out and the helmet was crushed to the point where the internal ear cups touched each other. On retrieving the helmet, it appeared to return to its normal shape and there appeared to be no structural failures. The visor was replaced and the helmet was put on to determine if there was any misalignment of the helmet ring. The helmet mated perfectly with the ring and the life support system was put into service to determine if the system remained tight. All checks indicated that the system was tight.

Since the system appeared to be air-tight and only one helmet had been taken into the mine, the test program was continued. The miner proceeded to make a cut of coal. These activities were documented on film using a Super 8mm movie camera and a 35mm camera. He had no difficulty in operating the cutter. However, the neck collar seemed to bother him as he tried to look to the rear. This was his only problem; however, he was able to compensate for it. There appeared to be no problem with the location of the miners' lamp on the helmet and visibility through the visor appeared to be good.

One problem developed as a result of the accident with the helmet. The internal air distribution system in the helmet had been ruptured and only half the visor stayed free of fog. The part that did fog up was not unbearable and the man was able to continue operating his equipment for the duration of the test program. He did comment that the chiller was keeping him too cold, and that there had to be a better means of controlling the temperature of the air in the system.

The following day, the other miner was brought into the mine to operate the roof bolter. He had previously operated this machine while using the life support system and had no problem. This was again the case. All activities were again documented on film.

In the following test, the No. 2 miner in the life support system operating the coal drill drilled the face that had previously been cut. The coal drill was somewhat unfamiliar to this miner, and the operation was rough. However, he had no problems in maneuvering the machine or in observing what he was doing. Drilling time did not appear to take any longer than a normal drill sequence. Here again, these activities were documented on film.

Following the drilling operation, the No. 1 miner with the life support system in the portable mode proceeded to charge and shoot the face. The

rebreather was placed in a standard "Flexible Flyer" wagon purchased for small hauling jobs in the mine and to demonstrate a means of handling the rebreather in the portable mode. With this he was able to pull the rebreather behind him and let it sit away from the area where he was working. He had no problems in planting the charges or making connections. Care, however, was exercised to keep his shooting cable from becoming tangled in order to facilitate the pulling of the wagon while laying the cable prior to firing the shot.

The following day, both miners wearing life support suits entered the mine and proceeded to load the coal onto the belt conveyor. The No. 2 miner's regular job was that of loader operator and the No. 1 miner's regular job was shuttle car operator and roof bolter. They mounted their life support systems on their respective pieces of mining equipment and proceeded to load coal. There appeared to be no problem in this operation. The loader had complete control of his equipment, complete visibility, and was hampered in no way. The dust created by the loading operation appeared to be repelled by the visor on the helmet so as not to cause a visibility problem.

The shuttle car operator was able to observe the loading of the shuttle car and change his position without difficulty. He had no problems in unloading the machine onto the belt conveyor at the other end. These sequences of operation were also documented on film.

Figure 24 shows the miner kneeling beside the loader. Note the location of the life support system on the loading machine. Figure 25 shows the miner operating the loader.

Figure 26 shows the No. 1 miner tramming the shuttle car towards the belt heading. Note the location of the rebreather on the shuttle car. Figure 27 shows the shuttle car operator in the alternate position. Note the load of coal on the conveyor beside his helmet.

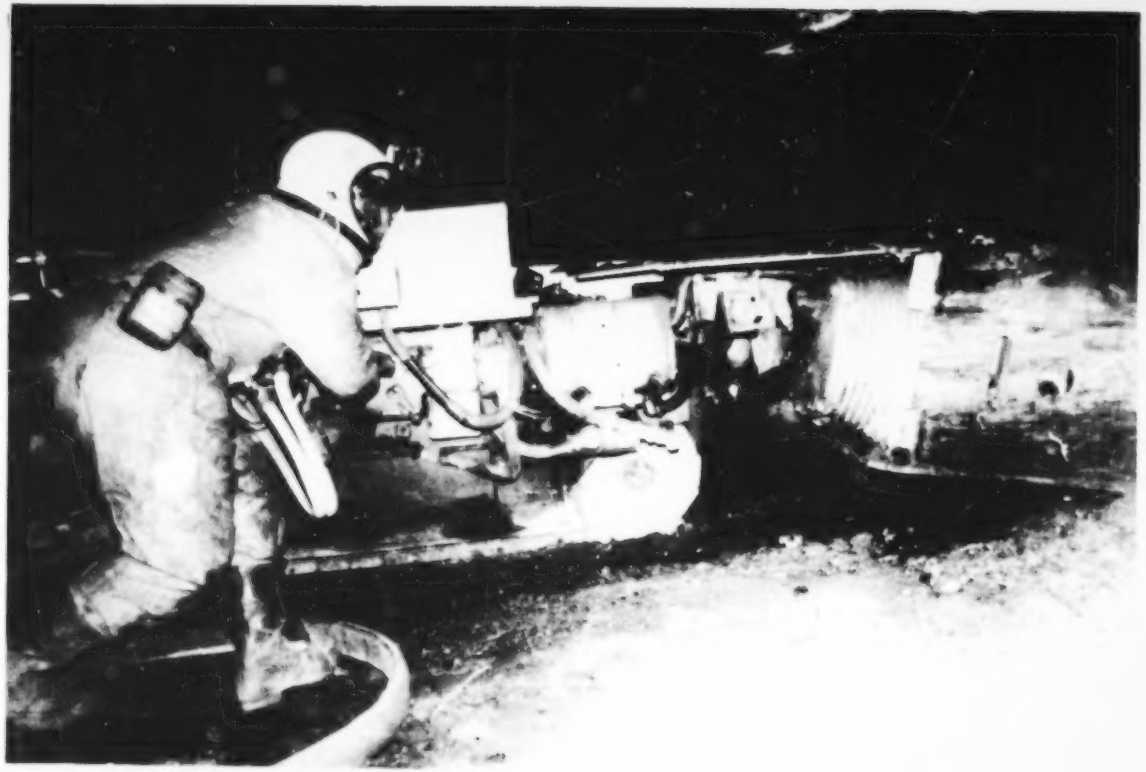
Figure 28 shows the roof drill in operation while Figure 29 shows the maneuvering of the machine.

Figure 30 shows the miner operating the coal drill. In no way does it hamper his visibility or his ability to operate the machine.

During the use of the roof bolter (pin machine) a hydraulic fitting on the underside of the machine was ruptured. In order to demonstrate the ability of a suited man to make equipment repairs, it was decided that one of the men would repair the machine while in the life support suit. The No. 1 miner trammed the roof bolter to an appropriate area for repairs. The procedure to be used to make the repair was reviewed with the test engineers and the miner proceeded to replace the broken fitting. The total time required to make the repair was approximately 12 minutes.

Miner and the Loading Machine

Figure 24



Miner Operating the Loading Machine

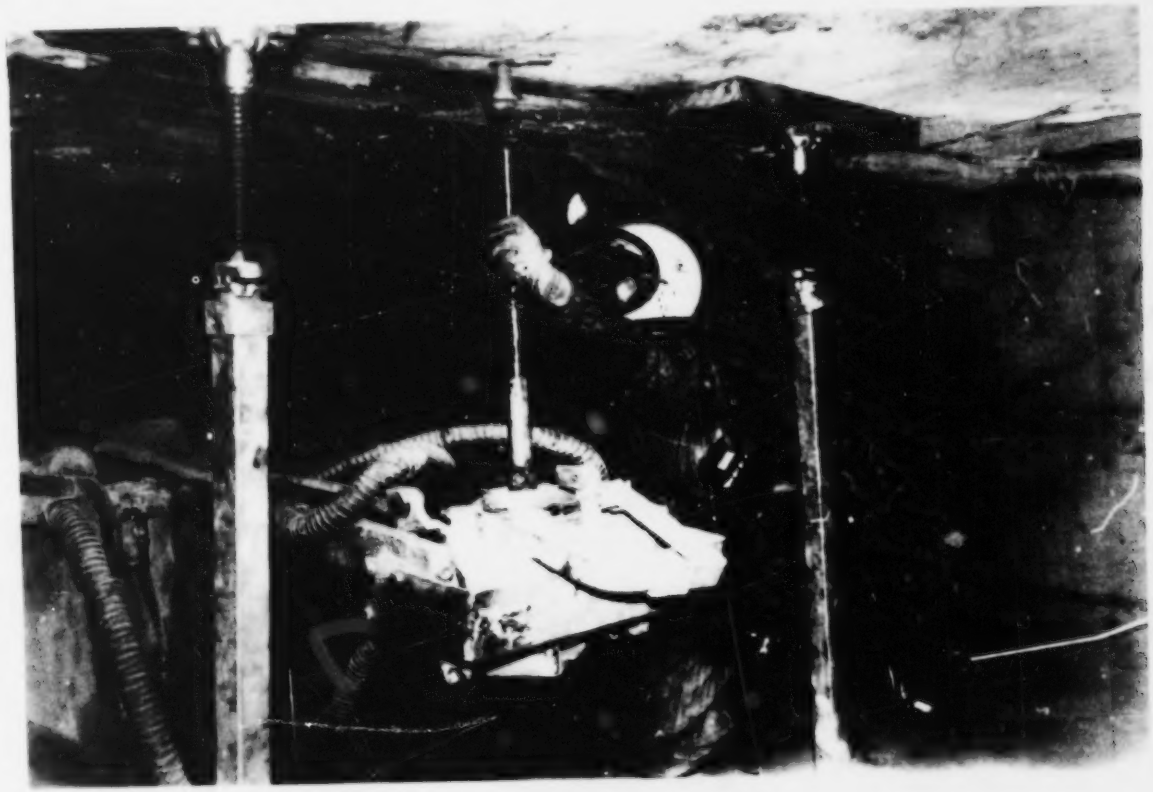
Figure 25

Miner Tramming the Shuttle Car

Figure 26

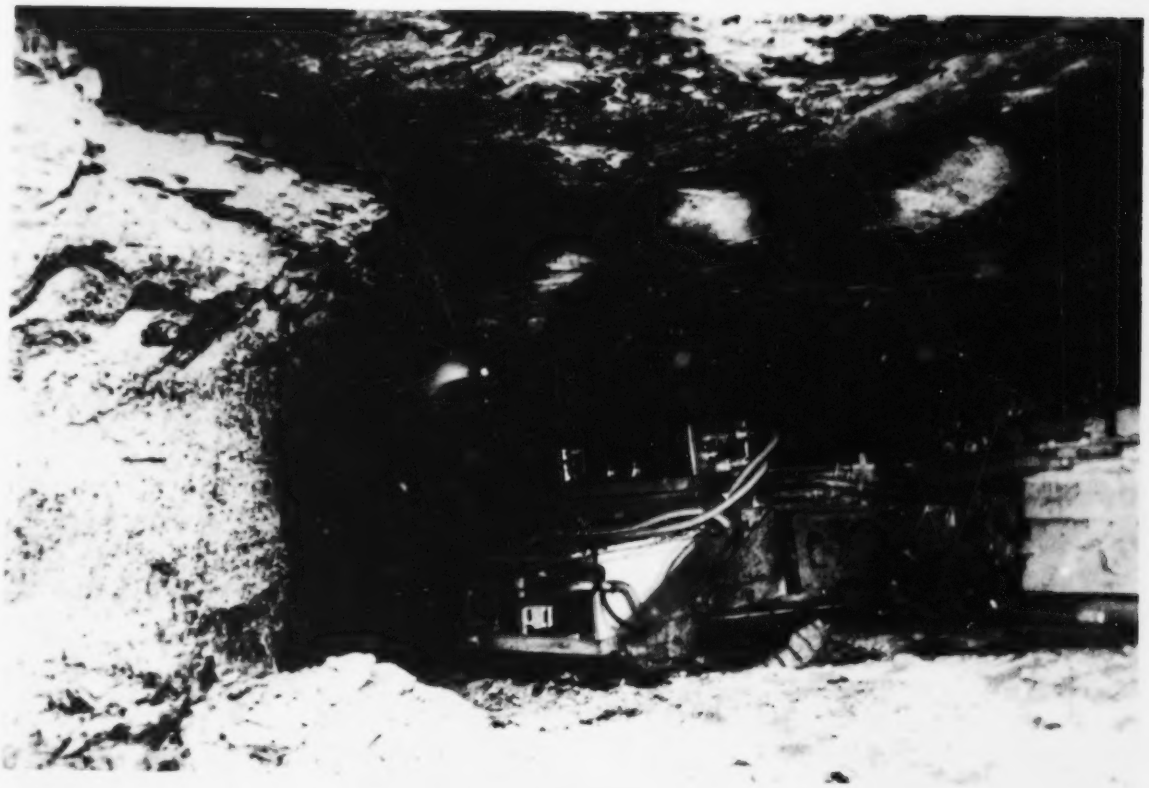
Miner Loading the Shuttle Car

Figure 27



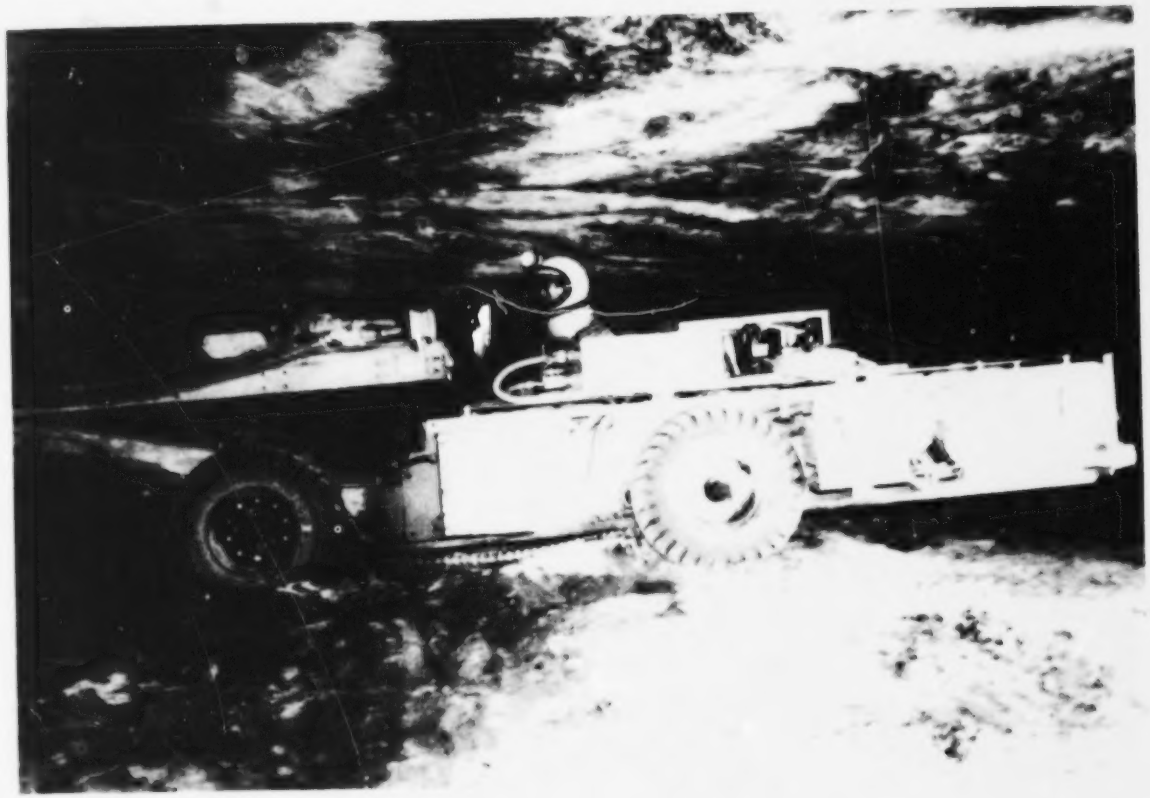
Miner Operating Roof Bolter

Figure 28



Miner Tramming the Roof Bolter

Figure 29



Miner Operating the Coal Drill

Figure 30

During this operation, the miner was required to bend down and look up underneath the machine. The machine had previously been blocked up to give him working room. Whenever he looked under the machine, the helmet stayed firmly on his head and did not slip one way or the other. It presented no problem at all. The standard miners' helmet would have fallen to the ground. This further demonstrated the ability of the simple stretch garment to control the helmet-rise problem and that the helmet presented no problem as far as maneuverability nor did it hinder the ability to perform in-mine tasks.

To further demonstrate the capabilities of a suited miner to perform in-mine work, two timbers were knocked down and reset. There were no problems in setting the timber, picking up the wedges, placing the wedges and driving them home. The life support system was attached to and powered by an adjoining piece of mining equipment. The man was able to stay cool and still had ample room to perform this work. These activities were recorded on film.

In order to demonstrate additional freedom of the system, the miner, with the life support system still attached to the machine, dismounted, picked up a shovel and proceeded to clean the ribs or shovel coal from the side of the mine into the center for pick up by the loader. He performed this work without any problems and the tethers did not interfere with his actions. He remained comfortable and did not break a sweat while doing this work.

The many project delays reduced the in-mine testing period to six weeks, making it impossible to carry out the program of testing, modifying, and re-testing the equipment in order to develop a reliable system. The delays in getting to the test face caused by long waiting periods for transportation to get in and out of the mine consumed considerable time, limiting in many cases the time in the mine to three hours or less.

In addition, several tests had to be terminated due to mechanical failures in the chiller and rebreather systems. The initial test was carried out only because the helmet that had been crushed was able to be kept in service. On at least two occasions, vibrations caused leaks to develop in the mechanical refrigeration systems causing the loss of refrigerant and resultant cooling. At least two fittings were accidently torn off of the chiller unit, putting them out of service. The fragile construction and the protrusion of the fittings were the basic cause of these failures. A complete redesign of the chillers is required to overcome these problems before additional testing is undertaken.

On another occasion, the oxygen sensing line protruding from the tether and connected to the rebreather was broken off. It was accidental, but it did pinpoint how fragile the system was and that a more rugged and reliable system of controlling the oxygen injection into the system must be developed.

The oxygen sensors in each of the rebreathers failed. An investigation into the cause revealed that the sensor, under normal conditions, had a one

year life, which had been exceeded. It was therefore necessary to purchase new oxygen sensors before testing in the mine. The location of the oxygen indicator on the rebreather presented a problem. On one piece of equipment, when passing through the mine curtains, there was enough friction to turn the oxygen monitor off or on, depending on which direction you were traveling. This created some problems and a method must be developed to control this.

Towards the end of the project, there was no emergency battery power in the rebreathers. Even though the lights on the battery charger indicated the battery was fully charged, they weren't. The shelf life of these batteries had apparently been exceeded and there were no replacement units on hand. As a result, tests in the portable mode could not be performed. All tests had to be conducted while the rebreather was plugged into the power source on the nearest piece of mining equipment. The battery system should be redesigned to facilitate the easy changing of batteries. In addition, a battery charger in the service building or in the mine could serve as a source of recharged batteries for extended emergencies.

Toward the end of the project, some of the blowers appeared to be laboring and not performing the way they did when they were new. Part of this could be directly related to the battery failures. However, it also appeared to happen when operating on the 24V external power supply. This problem was not resolved and should be investigated prior to considering the continued use of these blowers.

The locations of the rebreather and chiller on the mining equipment appeared to be satisfactory in most cases. However, the rebreather on the loader was pinched against the mine roof. The case was knocked out of shape; however, the internal mechanism of the rebreather continued to function. Every effort should be made to make the rebreather smaller, more compact, lighter in weight, and easier to carry.

The initial tether length of 9 feet was chosen as this was the standard length in which the hoses were made. This length was satisfactory for most jobs in the mine. However, there was not enough time to determine the optimum length of tether required for each operation in the mine. An expandable tether system expanding from the compressed state of six feet in length to an expanded length of 18 feet would be most desirable. Such hoses are on the market and should be investigated for this use.

In summarizing the in-mine testing program, the miners were able to operate their mining equipment and perform various in-mine tasks while wearing the life support system. The malfunctions experienced with the mechanical end of the system indicate a definite need for further testing and redesign of the life support equipment in order to develop a reliable and foolproof system.

RECOMMENDATIONS

The following should be taken into consideration when redesigning the life support system.

Rebreather

- All electrical components should meet permissibility requirements.
- Batteries should be installed in such a manner as to be easily replaced.
- The recharge rate of the batteries is too long--16 minutes recharging for each minute of use. Alternate methods of recharging the batteries should be considered, including the use of a rapid pulse recharger.
- The in-mine storage of charged batteries and the replacement of these batteries in the mine should be considered.
- The entire unit needs to be reoriented to make it smaller and more compact.
- The case should be constructed of nonconductive material.
- All materials of construction should be reviewed to conserve weight.
- A review of the need for the DP cell should be made. Its function does not appear to justify the additional weight and space.
- The CO_2 canister should be redesigned to be more compact, lighter, less subject to corrosion problems, and easier to service. Prepackaged units already available on the market should be considered for this use.
- The tether connections would be more convenient if they were on each side of the carrying handle on the case. This would eliminate dragging the tethers with the possibility of catching them on something.
- A more reliable means of oxygen control is required.
- All units should be readily replaced. The need for modifying purchased subassemblies should be eliminated.
- The blower selection should be reviewed for serviceability.
- Alternate life support schemes should be reviewed such as a small portable unit to enter the mine in the portable mode, and then connectable to the main life support unit mounted on the machinery. The portable unit would also serve as an emergency backup unit.

Chiller

- The present mechanical chiller should be redesigned to eliminate vibration failures and to make it more compact.
- All fittings should be located so as to be protected against accidents that would break them off. The construction of the unit should be reviewed to strengthen these fittings.
- A better temperature control is required. The main complaint was that of being too cold.
- The overall size of the unit needs to be reduced to facilitate mounting on the mining equipment.
- The use of a hydraulic turbine drive for the unit should be investigated.
- The use of a power takeoff from the hydraulic pump drive should be investigated.
- The mining equipment manufacturers should be contacted to review these possibilities and assist in mounting the chiller on the machine.
- Additional testing should be conducted with the thermionic chiller to evaluate its overall capabilities. Due to limited in-mine testing this unit was not adequately tested.
- A compressed gas operated chiller should be developed for short term uses such as on the porta-bus and boss cars where available power may be limited.
- Other means of cooling should be investigated.

Life Support Suit

- Review the design of the helmet and neck area in an effort to reduce the weight and bulk of the unit and to facilitate ease of head movement.
- Review the tailoring of the stretch garments to facilitate donning and comfort. Those tested tended to be too confining and created some pressure points. A larger suit of the same design may be required.
- The internal air ducts created pressure points in several places, particularly the neck area. Location and construction of these ducts should be reviewed.
- A quicker means of removing the visor under emergency conditions is required.
- The air flow noise in the helmet needs to be reduced and air distribution across the visor needs to be improved. The left side of the visor had a tendency to fog while the right side remained clear.

Emergency Rebreather

- Alternate emergency rebreathers should be investigated to reduce the weight and minimize operator interference. The operator continually was adjusting the unit to keep it out of the way.

- Future emergency rebreathers of the type tested should be packaged with longer neck straps. The present neck strap is not long enough to go over the man's helmet. This caused a delay in activating the unit and the total weight of the unit was supported by the bite mouthpiece while he tried to slip the strap around his neck.

SECTION XIII

WATER ANALYSIS

A water sampling program was undertaken on the Price Branch of Pond Fork Creek in order to develop background information by characterizing the water quality in the area. The demonstration mine site is located near the head waters of Price Branch and any water drainage from the demonstration mine could affect the water quality in Price Branch. This background information will play an important part in evaluating the effects of the demonstration mine water discharge.

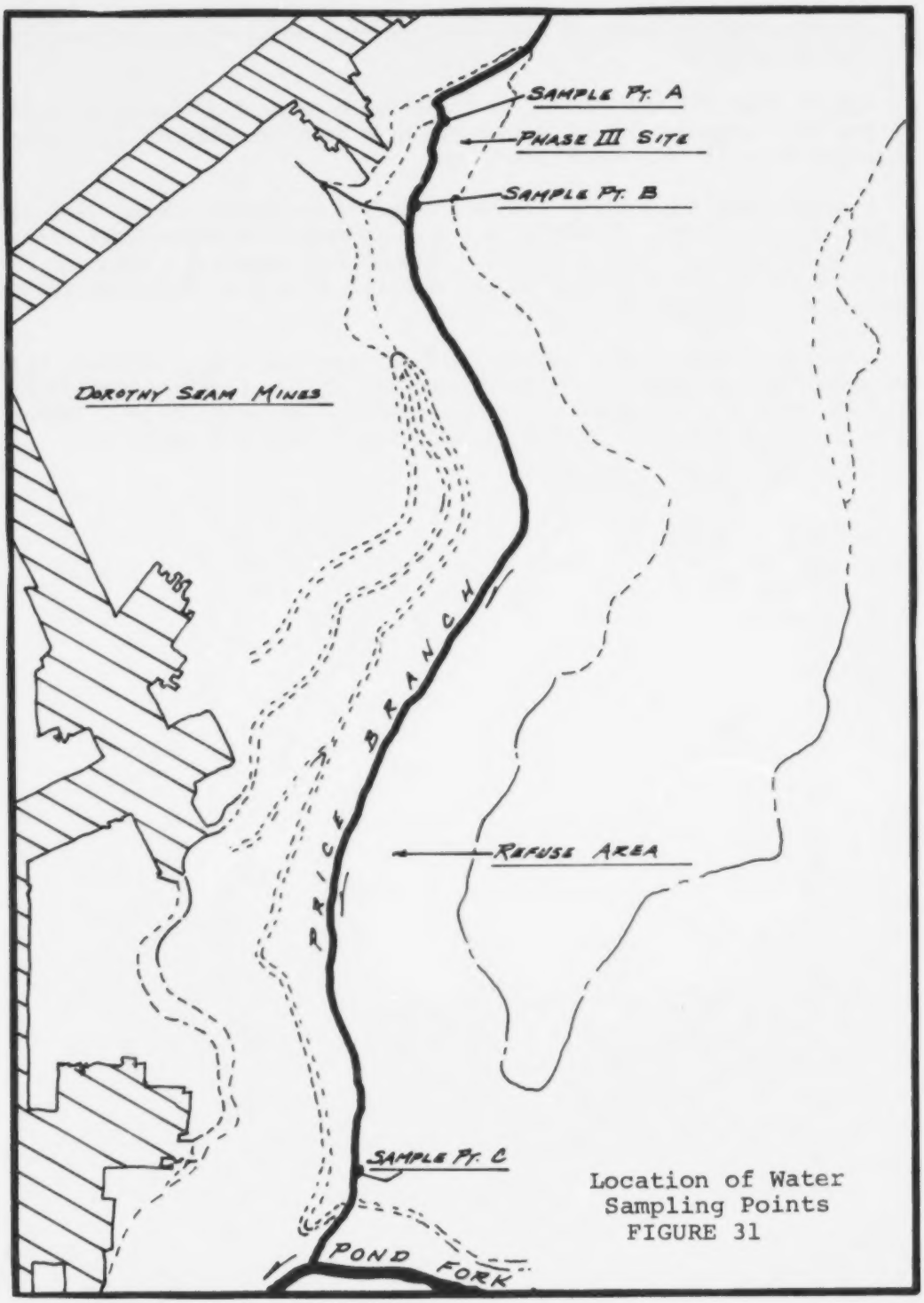
Strip miners have been active in the Price Branch watershed. The outcrop of the Dorothy seam has been auger mined in its entirety except for the section set aside for the demonstration mine portal. The spoil has been pushed over the side of the mountain and could adversely affect the quality of the drainage water in the area. The Number Five Block coal seam approximately 150 feet higher up the mountain than the Dorothy seam has also been auger mined and its spoil pushed down the side of the mountain. Drainage from the Number Five Block area constitutes part of the head waters of Price Branch.

Midway down the valley between the demonstration mine site and Pond Fork is the sludge lagoon serving the preparation plant for Pond Fork Mine. Price Branch water coming down the valley flows underneath the sludge lagoon through a culvert pipe. Local sand, gravel, and clay was used to backfill around the culvert pipe to form the bottom of the sludge lagoon and to act as a filter for lagoon water percolating into the culvert pipe. Coal mine refuse was used to construct the contaminant dam to create the sludge lagoon. Drainage from the sludge lagoon could also affect the quality of the water being discharged from Price Branch into Pond Fork Creek.

Three sample points were established to determine the effects of the various operations in the valley. Figure 31 is a map of Price Branch showing the location of the various sampling points as well as the location of the demonstration mine and the main portal of Island Creek's Pond Fork Mine.

Sample point "A" represents the drainage water above the demonstration mine site and was taken at the discharge of the culvert under the road serving the demonstration mine site. This water drains down the valley from the stripped mined area above and reflects this operation.

Sample point "B" is below the demonstration mine site and just above a small stream draining a smaller water shed. Strip mine spoil from the Dorothy seam could affect this water quality. Samples A and B represent the



Location of Water
Sampling Points
FIGURE 31

water supplied to the demonstration mine site and the waters below the site.

Discharge waters from the demonstration mine would affect the quality of the water at point B.

Sample point "C" was taken just above the mine road bridge serving the area and is a composite of all waters draining down the valley. This water discharges directly into Pond Fork Creek.

A random sampling program was conducted and all samples were taken within one hour of each other. No effort was made to determine water flows nor to correlate analyses to flows. Tables 1 through 7 in Appendix L show the comparison of the results for each set of samples. Figure 32 shows the maximum and minimum values for each sample point.

A review of the various tables indicates that the mining activity in the water shed has not materially affected the quality of water discharging into Pond Fork Creek. If anything, the water slightly increases in pH. There is little change in the water quality between sample points A and C.

FIGURE 32

WATER ANALYSES - RANGES

Determination	Sample Location Point A min-max	Point B min-max	Point C min-max
M.O. Alkalinity ($CaCO_3$)	26-75	23-60	24-52
Total Acidity ($CaCO_3$)	3-14	4-24	2-8
Chloride (Cl)	1.49-1.87	1.56-1.84	---
Sp. Conductance (25°C) μ mhos/cm^2	149-220	134-200	---
pH (units)	6.7-7.7	6.7-7.7	7.2-7.5
Calcium (Ca)	27-27.2	19.2-27.0	---
Magnesium (Mg)	9.6-19	13.4-16	---
Hardness Total ($CaCO_3$)	61-180	65-170	73-128
Sulfate (SO_4)	31.9-74	27.2-67.0	44.6-86.2
Iron Total (Fe)	0.33-5.0	0.29-55	2.0-21
Total Matter	128-251	49-2,640	213-1,020
Suspended Matter	4-31	19-2,519	59-841
Dissolved Matter	117-220	29-212	179-220
Aluminum Total (Al)	<0.1-5.9	<0.1-63.5	3.0-30.0
Manganese (Mn)	0.08-0.57	0.07-1.6	0.22-0.88

All results reported as parts per million (ppm) unless otherwise noted.

Point A - above Demonstration Mine Site
Point B - below Demonstration Mine Site
Point C - drainage from valley before entering creek

SECTION XIV

DEMONSTRATION MINE DESIGN

As a result of the Phase I study, the Pond Fork Mine of Island Creek Coal Company was selected as the site for the proposed demonstration mine. The demonstration mine is to be located in the Dorothy seam approximately 3500 feet around the mountain from the main portal to the Pond Fork Mine and approximately one mile from the Phase II office. The outcrop of the Dorothy seam had been auger mined. However, a block of coal was left unaugered for the portal to the demonstration mine. An access road is available to the site and a major part of the grading has already been completed. Additional site preparation will be required to provide adequate drainage in the area. Approximately 150 feet above the Dorothy outcrop, the Number Five Block coal seam had also been auger mined. Spoil from the Number Five Block operation was pushed down over the mountain and is a threat to the demonstration mine site. This must be removed prior to the construction of the mine.

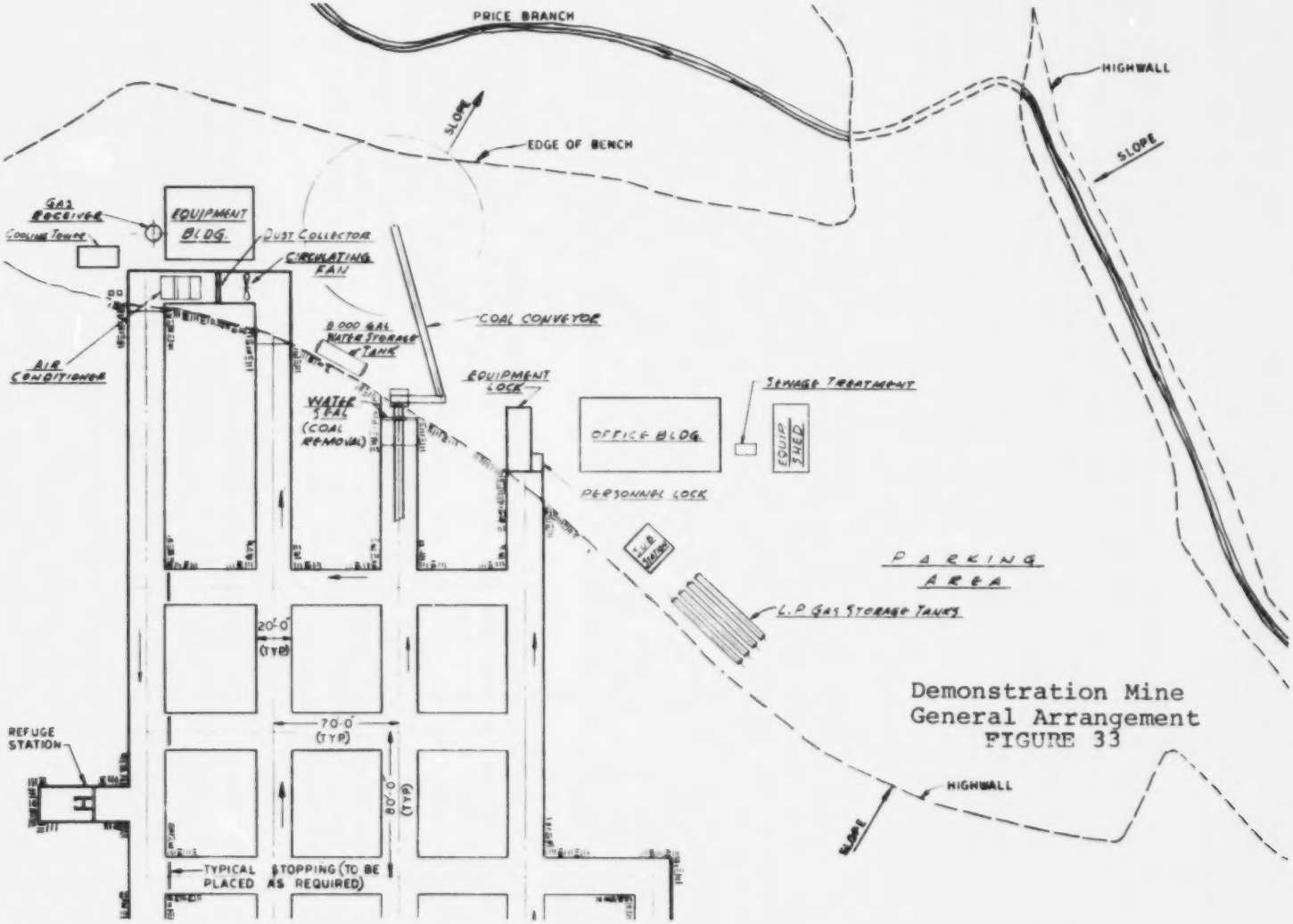
The demonstration mine site is located at the headwaters of the Price Branch of Pond Fork Creek. All coal removed from the mine will be trucked down the hill to the present preparation plant for the Pond Fork Mine. Power is available within 500 feet of the mine site. However, water must be piped to the site.

Each recommendation of the Phase I study was reviewed and in a few cases, changes were made. Two gas generators were used instead of the previously recommended gas holder. Continuous purging of the gas locks was used rather than the demand purging proposed in Phase I. The double hopper coal removal system was replaced with a water seal system. Figure 33 shows the general arrangement of the demonstration mine.

Gas Blanketing Systems

A review of blanket gas requirements in the Phase I report indicated that the gas holder was expensive and unnecessary. In its place, two inert gas generators were used to meet the peak demands required during the locking of personnel and equipment into the mine. In addition, a high pressure gas supply was used to purge the personnel lock at the refuge station. This required the use of an inert gas compressor and receiver.

A review of the various inert gas generators available indicated that most generators used direct contact with water to cool the inert gas and the exit gas from the generator was saturated with water. The inert gas generators chosen for the demonstration mine utilizes indirect cooling of the exhaust gas and the gas is not necessarily saturated with water. Two 40,000 cubic feet



Demonstration Mine
General Arrangement
FIGURE 33

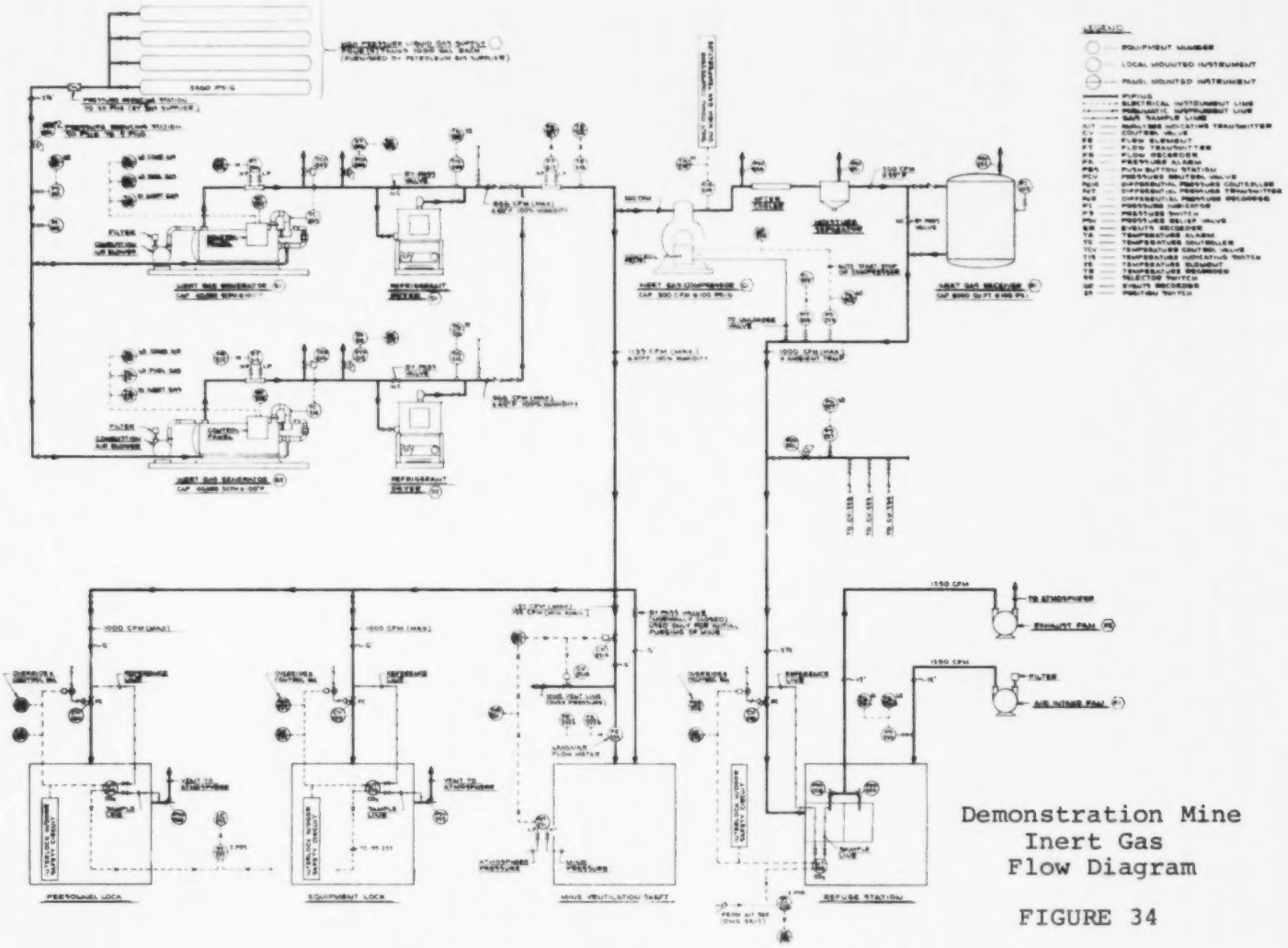
per hour gas generators were selected. The size was dictated by the criteria that one thousand cubic feet per minute of purged gas be used when purging the personnel and equipment locks. This was by far the greatest single use of blanketing gas and by satisfying these requirements, all other gas demands would be met.

The two inert gas generators have a maximum capability of 1333 cubic feet of inert gas per minute. Each generator can be throttled back to produce one-third of its normal output and still meet the inert gas criteria. The minimum output of the system would be obtained by running one generator at one-third capacity and would amount of 222 cubic feet of blanketing gas per minute. Each generator can be throttled back individually or in unison to produce any volume of gas from one-third the capacity of one generator to full capacity of both. The system is therefore capable of supplying 222 to 1333 cubic feet of blanketing gas per minute. If less than 222 cubic feet of gas per minute is required, the unused portion will be vented to the atmosphere and only that gas required for the system will be used.

To supply the compressed gas to operate the personnel lock at the refuge station, a 200 cubic feet per minute gas compressor was used to maintain a 100 pounds per square inch pressure in an 8000 cubic foot gas receiver. The discharge of the receiver was piped into the mine to operate the gas lock at the refuge station. The gas compressor will automatically keep the pressure in the receiver at 100 pounds per square inch as a result, there will be enough gas in the receiver to operate the gas lock in the refuge station for approximately five cycles, even under power failure conditions. Under the maximum gas generator output, 1000 cubic feet per minute of gas is required to operate the personnel lock, 200 cubic feet per minute for the gas compressor, and the remaining 133 cubic feet would be available to maintain the in-mine pressure.

One of the ultimate goals of the demonstration mine is to evaluate the humidity increase within the sealed mine. It is predicted that 100% humidity will be reached and maintained in the mine at all times. The dew point of the blanketing gas from the selected gas generators is therefore considered critical. To eliminate this variable, each gas generator was equipped with a refrigerant dryer capable of drying the total gas flow from the generator to produce a 40°F dew point gas for in-mine use. This represents a gas containing 40% relative humidity at 70°F, which is the projected operating temperature of the demonstration mine.

A review of the various fuels available for operating the inert gas generators showed that natural gas was not available. It was therefore necessary to consider either liquid petroleum gas or fuel oil. Liquid petroleum gas was the selected fuel for firing the inert gas generators. The fuel oil added contaminants to the gas stream which were undesirable. Figure 34 is the flow sheet showing the blanketing distribution system.



Demonstration Mine
Inert Gas
Flow Diagram

FIGURE 34

Coal Removal System

Phase I recommended a double hopper system with inert gas purging to remove the coal batchwise from the mine. Further investigation into this problem resulted in the design of a water seal that permitted the continuous removal of the coal from the mine while still maintaining a positive seal on the mine. A standard drag tank used in coal preparation plants throughout the coal industry was determined to be a suitable piece of equipment to accomplish this goal. Figure 35 shows the general arrangement of the water seal. Figures 36 and 37 show further details of the system.

The coal is discharged off the end of the belt conveyor behind the mine seal inside the mine into a chute which conducts the coal into the side of the drag tank and below the water level. The water seal is maintained in the coal chute. The drag conveyor removes the coal from the tank as rapidly as the belt conveyor feeds it into the chute. The coal is discharged onto a stacking conveyor which elevates the coal and stacks it on the ground. A make-up water system assures a sufficient quantity of water at all times to maintain the seal. All runoff water is recovered for reuse.

Dust and Heat Control

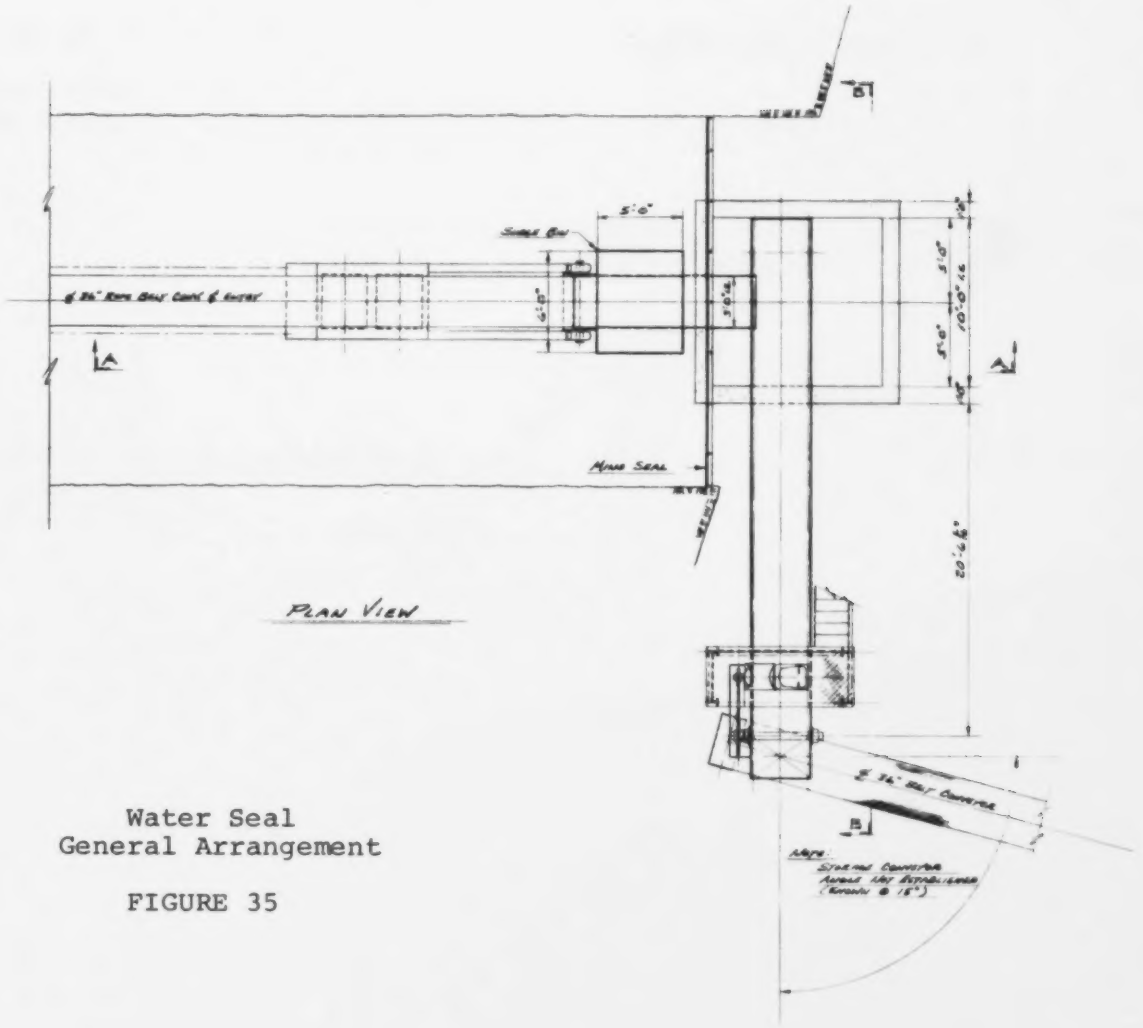
The dust and heat control systems incorporated into the mine design are basically those recommended in the Phase I report. The mine atmosphere will continually circulate through the mine using a standard mine ventilation fan. Ducts were provided so that the air flows out one entry, through the fan and returns to the mine through another entry. The ducting was designed so that it could be rapidly converted to a normal mine ventilating system.

The initial heat control system recommended in Phase I included the use of a 50 ton air conditioning unit for humidity control in the mine. Various systems were reviewed and a standard, air-cooled, air conditioning unit was chosen for the system. This packaged unit is not directly in the air stream, but in a bypass stream and can be used or bypassed as the test requirements for the project dictate.

A standard Rolomatic off-the-shelf dust collector was incorporated into the air flow pattern as it provided a minimum resistance to the air flow in the system. In all cases, all equipment was installed downstream of the ventilating fan in order to minimize the negative pressure on the suction pressure in the entire system.

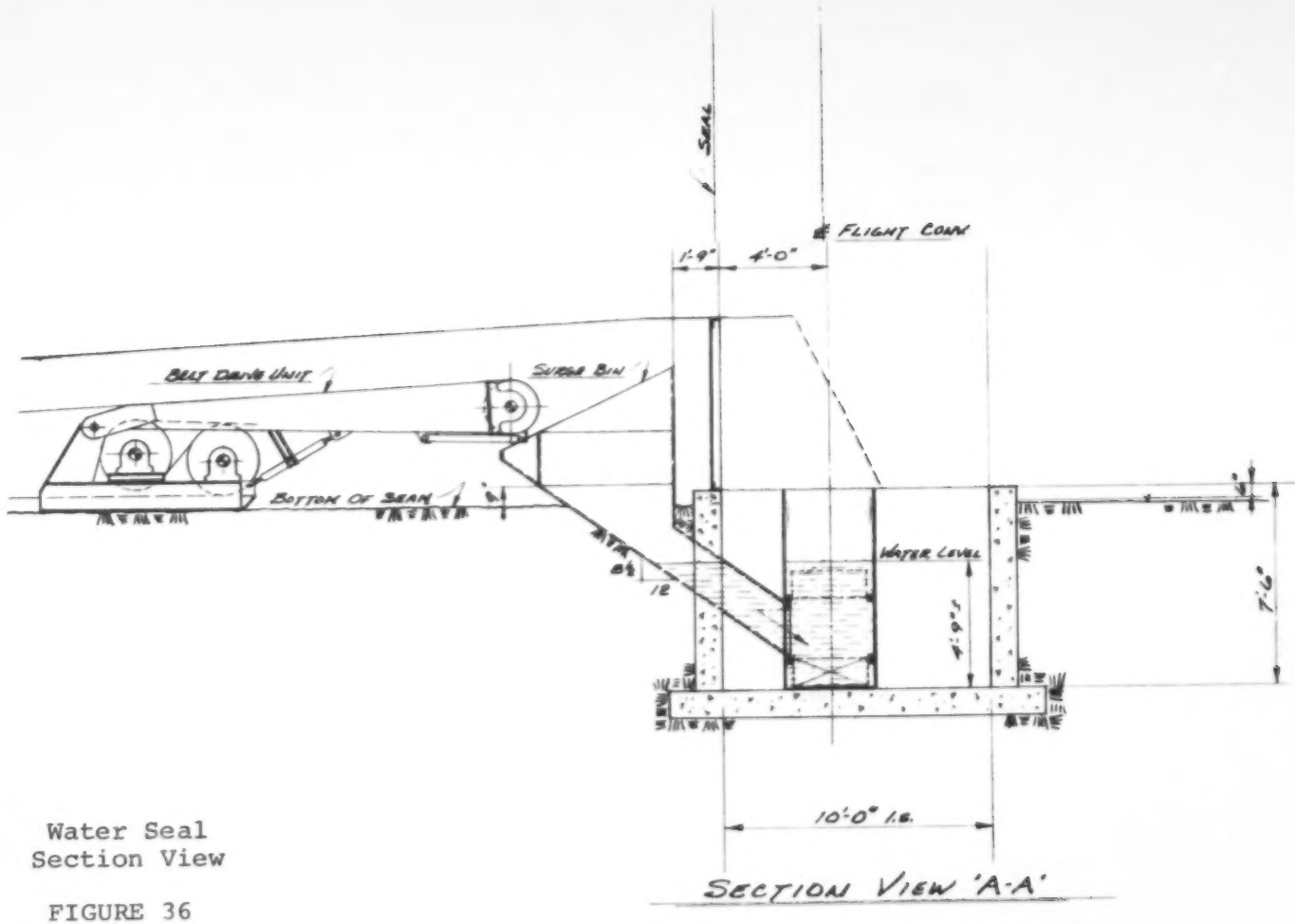
Gas Locking System

The Phase I report called for the demand purging of the various locks incorporated in the system. This meant that the lock was purged only when somebody wanted to pass through and the purge cycle had to be manually activated. This would be the ideal operating sequence for these locks to conserve purge gas. However, in-leakage from the mine and the refuse station and the outside into the respective locks could be a problem. As a result, an automatic purge system was incorporated into the mine design.



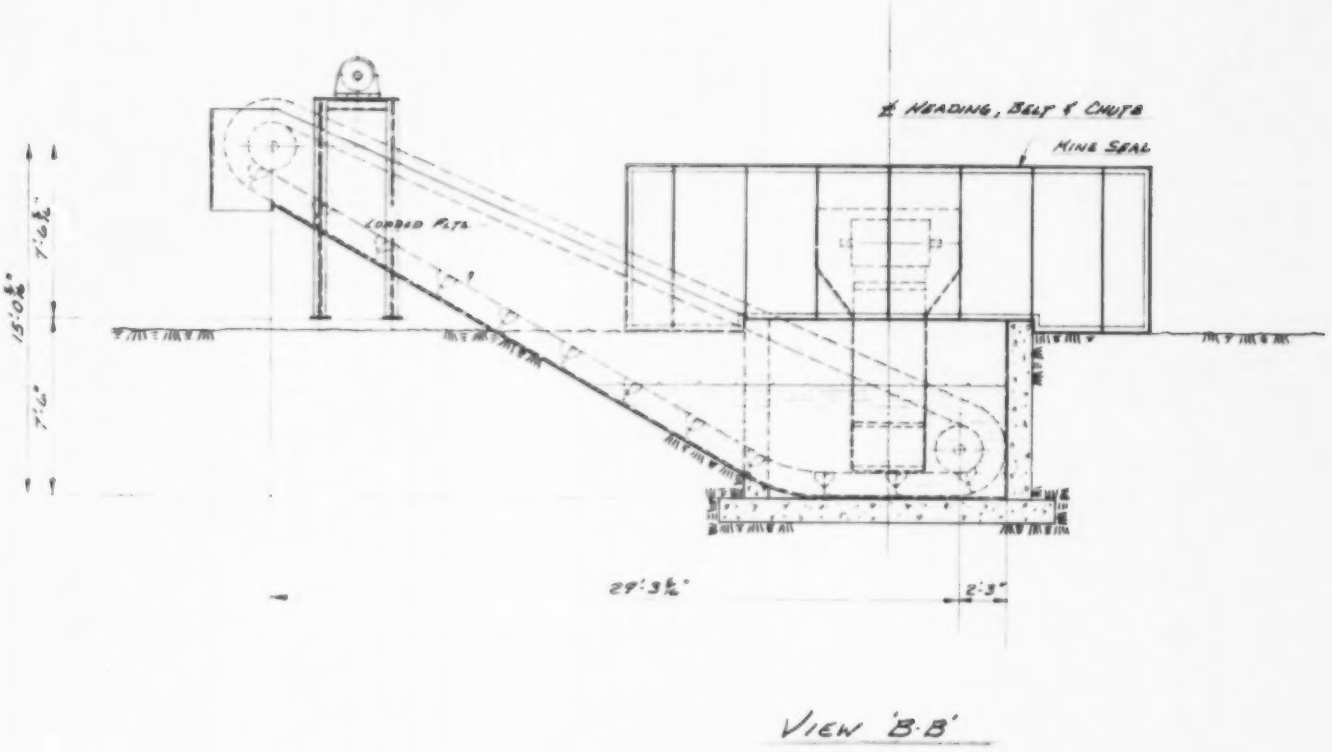
Water Seal
General Arrangement

FIGURE 35



Water Seal
Section View

FIGURE 36



Water Seal
Elevation Section

FIGURE 37

This system incorporated an automatic carbon dioxide analyzer using a reference cell to compare the composition of the gas in the gas lock to the composition of the gas being used to purge the lock. Once these two compositions were equal, the purge cycle would shut down. Should there be any leakage into the gas lock that would change the composition of the gas in the lock, the purge cycle would automatically restart and purge the lock until once again the analyses of the two gases were the same. Interlocks were provided to prevent the activation of the purge cycle while entering the gas lock.

By using the automatic purge cycle, the leakage of air from one area to the other will be held at a minimum, and it in no way overburdens the capabilities of the gas generators to supply the gas.

The gas lock at the refuge station will operate from the 100 pounds per square inch supply of high pressure gas which will deliver 1000 cubic feet per minute of gas to the lock. High pressure gas was chosen as the least costly route to accomplish the job. This lock will utilize the automatic purge system as described. The only difference between it and the personnel lock is the use of the high pressure gas.

Refuge Station

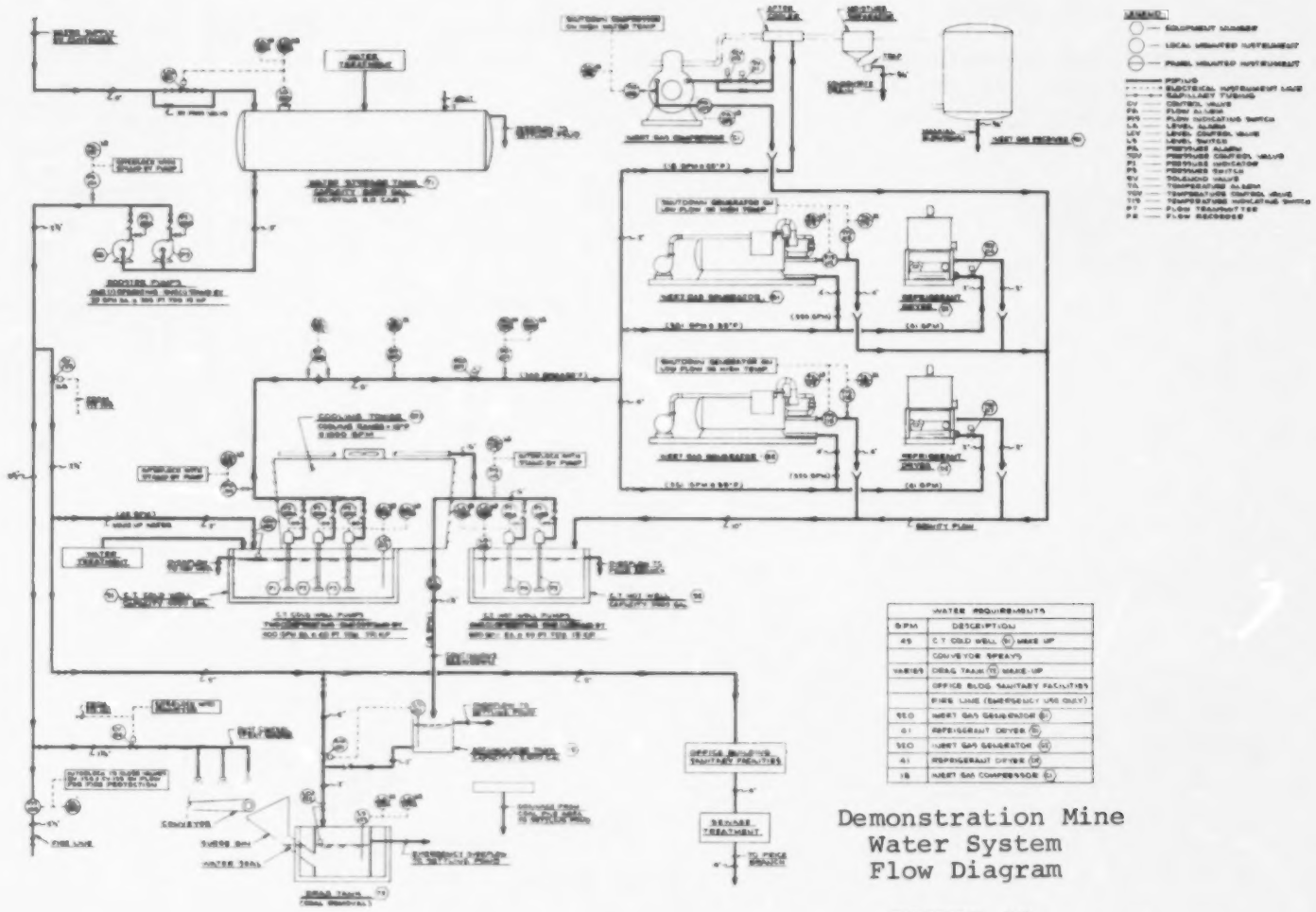
The Phase I report indicated that a bore hole system would be used to ventilate the refuge station. A review of this concept, both from an engineering and cost standpoint, indicated that for this particular instance it would be better to ventilate the refuge station by running ducts from the mine mouth to the refuge station. Fresh air from the mine mouth would be blown into the refuge station and the exhaust air returned by the same route. This scheme was incorporated into the demonstration mine. In all cases, standard off-the-shelf equipment was used.

Instrumentation

A complete instrumentation system was developed to control the blanketing gas system. A similar system was developed to control the cooling water circuitry required for the inert gas generators, refrigerant dryers, air compressor, and water seal. The water system incorporated the use of a cooling tower in order to minimize demands on make-up water. Figure 34 is the flowl diagram showing the inert gas system and Figure 38 is the flow diagram for the water system.

Additional instrumentation recommended in the Phase I report was provided to continuously monitor the various atmospheres in the mine, in the gas lock, in the personnel lock, and in the refuge station. Additional instruments to measure gas flow in the mine, dew point and temperature were included. A complete weather station was also incorporated into the system in order to evaluate the effects of weather changes on the operation of the mine.

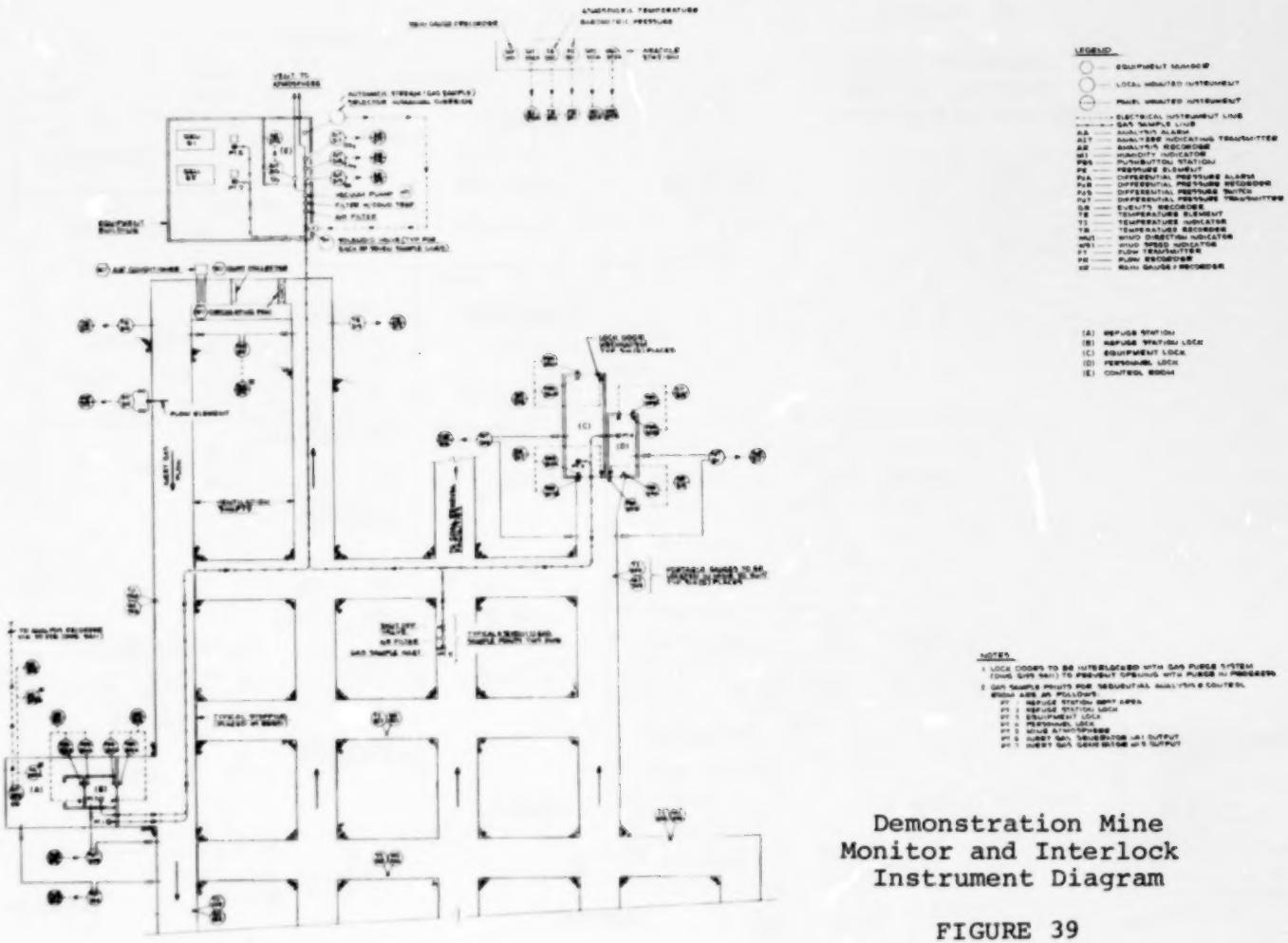
Figure 39 shows the monitors and air lock instrumentation incorporated in the mine.



WATER REQUIREMENTS	
GPM	DESCRIPTION
45	C.T. COLD WELL (9) MAKE UP
	CONVEYOR SPRAYS
VARIES	DRAG TANK (11) MAKE UP
	OFFICE BLDG. SANITARY FACILITIES
	FIRE LINE (EMERGENCY USE ONLY)
950	INERT GAS GENERATOR (6)
61	REFRIGERANT DRYER (5)
950	INERT GAS GENERATOR (6A)
61	REFRIGERANT DRYER (5A)
18	INERT GAS COMPRESSOR (4)

Demonstration Mine
Water System
Flow Diagram

FIGURE 38



Demonstration Mine
Monitor and Interlock
Instrument Diagram

FIGURE 39

The demonstration mine was designed to be a one section mine operated by one crew one shift per day for five days per week. This was the recommendation of the Phase I report and was used in designing the demonstration mine. The change from the gas holder to two inert gas generators and the requirements for]000 cubic feet per minute purge rate in the gas locks dictated the size of the gas generating equipment. The gas requirements as calculated in the Phase I report were 400,000 cubic feet per day. The inert gas generators have the capability to supply five times this amount of gas or approximately two million cubic feet per day. This will enable the rapid purging of the mine initially and has the capacity to support a three shift operation.

Summary

Based on the above changes, the design of a demonstration mine was developed in a suitable manner so that a reliable estimated cost of the mine could be developed. Prior to the construction of the mine, additional detailed drawings will be required. The drawings listed in Appendix I were submitted to the Environmental Protection Agency and constitute the complete design of the demonstration mine.

SECTION XV

DEMONSTRATION MINE COSTS

The Demonstration Mine was designed for the purpose of determining the equipment and details required to construct and operate a mine under controlled atmospheric conditions in order to better understand how the mine would operate and to develop the associated cost to construct and operate the mine.

It was anticipated that the end result of this Phase II would be a tested and reliable life support system suitable for extensive testing in a demonstration mine. The next phase would be the construction and operation of a demonstration mine using a full crew equipped with life support systems. The mine would be operated for approximately six months under ventilated conditions to further test the reliability of the system. The oxygen would then be removed and the mine operated under oxygen-free conditions for a period of one year.

This line of thinking is still valid for the testing of a reliable life support system. However, the crew testing under ventilated conditions should be extended to a minimum of twelve months in order to permit any additional modifications and changes to the system to be thoroughly evaluated.

The overall length of the demonstration mine phase would be 48 months. This would involve the review and updating of the existing mine design, the preparation of detailed construction drawings, the purchase and delivery of the equipment, and the construction of the mine and associated systems. This would be followed by a period of miner training in the use of the life support system and the inert gas system check-out. These would require approximately two years to complete. Two twelve month in-mine test periods would then be undertaken--one under ventilated conditions and the other under oxygen-free conditions. Improvements in the equipment delivery and construction could reduce the overall length of the project.

The following costs were developed for the construction and operation of a demonstration mine for a period of 48 months:

Capital Costs

Gas Blanketing Systems per design drawings	$1,154,500
Additional Mining Equipment	251,500
Life Support Systems and Offices	483,260
Initial Capital Investment	$1,889,260

Operating Costs

Miscellaneous Supplies, Etc	276,100
Operating Labor	2,839,120
Total 48 Month Cost	$5,004,480

This is an annual operating cost of $778,805, which will be reduced through coal credits returned to the project. See Appendix N for a breakdown of these costs.

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